सत्यमेव जयते

INDIAN AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI.

I.A.R I.6.
GIP NLK—H-3 I.A.R.I.—10-5-55—15,000

臺北帝國大學理農學部紀要

第六巻　第一號

昭和七年七月

MEMOIRS
OF THE
FACULTY OF SCIENCE
AND
AGRICULTURE

TAIHOKU IMPERIAL UNIVERSITY

Vol. VI.-VII No. 1.

JULY, 1932

HAYASAKA, Ichirô: On Three Brachiopod Species of the Subfamily *Orthotetinae* in the Fusulina-Limestone of Kinsyôzan, Akasaka-Mati, Prov. Mino, Japan.

312232
IARI

PUBLISHED
BY THE
TAIHOKU IMPERIAL UNIVERSITY
FORMOSA, JAPAN

PUBLICATION COMMITTEE

Professor **Kintaro Oshima,** Dean of the Faculty (*ex officio*)
Professor **Ichirô Hayasaka**
Professor **Kichimatsu Matsuno**
Professor **Tokuichi Shiraki**
Professor **Tyôzaburô Tanaka**

The Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University, is published occasionally by the University and is distributed to institutions of learning throughout the world for exchange. Separate series will be sent to independent research institutions, and complete series to the central libraries of universities and major institutions. Copies of the Memoirs may also be obtained from Maruzen Company Ltd., Tôkyô, Japan.

All communications regarding the Memoirs should be addressed to the Dean of the Faculty.

臺北帝國大學理農學部紀要

第六卷

MEMOIRS
OF THE
FACULTY OF SCIENCE
AND
AGRICULTURE
TAIHOKU IMPERIAL UNIVERSITY

Volume VI. — VII

1933-1934

TAIHOKU IMPERIAL UNIVERSITY
FORMOSA, JAPAN

CONTENTS

Page

HAYASAKA, Ichirô: On Three Brachiopod Species of the Subfamily *Orthotetinae* in the Fusulina-Limestone of Kinsyôzan, Akasaka-mati, Prov. Mino, Japan. 1

HAYASAKA, Ichirô: On the Upper Carboniferous Brachiopod Fauna from the Nabeyama Region, Totigi Prefecture, Japan. 9

ICHIMURA, Takeshi: Bedded Hematite Deposits of the Rigen Mine, S. Kankyô-dô, Chôsen (Korea). 45

HAYASAKA, Ichirô: Fossil Occurrence of Pelecypod Shells Bored by Certain Gastropods. 65

ICHIMURA, Takeshi: Geological Notes on the Mozan Iron-bearing District, N. Kankyô-dô, Chôsen (Korea). 71

ICHIMURA, Takeshi: Cognate Inclusions in the Andesite Lavas from Shabôsan of the Daiton Volcanoes, Taiwan (Formosa).... 105

On Three Brachiopod Species of the Subfamily *Orthotetinae* in the Fusulina-Limestone of Kinsyôzan, Akasaka-Mati, Prov. Mino, Japan.

(With 2 Text-Figures and 2 Plates)

Ichirô HAYASAKA

I. INTRODUCTORY.

In an article entitled "On *Lyttonia* and Several Other Brachiopods from Kinsyô-zan", published in Japanese in 1925(1), I made mention of the occurrence of some brachiopods from Kinsyô-zan, Akasaka-Mati, namely,

Reticularia lineata MARTIN
R. *Waageni* LÓCZY em. FRECH
R. cf. *inaequilateralis* GEMMELLARO
Terebratuloidea (?) sp.
Lyttonia Richthofeni KAYSAR em. HAYASAKA
Scacchinella cf. *gigantea* GEMMELLARO (Text-fig. 1.).

It has long been known that various molluscs abound in the *Fusulina*-limestone of this locality, but brachiopods seem to have escaped the eyes of geologists for a long time. The paper cited above, though but a preliminary note, not only summarized for the first time the fossil brachiopods found there, but was the first record of the occurrence of *Scacchinella** in our country.

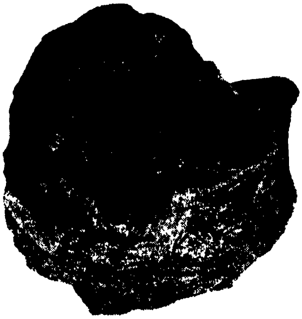
---

* At this place I intend to summarize the descriptive features of what I regarded as *Scacchinella* cf. *gigantea* in the preliminary report above cited because neither I nor OZAWA (see Reference 3) have tried to describe the specimens.

My specimen is a very incomplete one, being a broken piece of a ventral valve. It is roughly conical in outline, with an exceedingly high cardinal area which is slightly concave. By cutting and polishing the anterior end of the specimen, it is seen that a very strong median septum projects from inside the cardinal area, without an umbonal chamber, which is characteristic of an *Orthotetes* (Text-fig. 1). The maximum diameter of the conical body measures about 40 mm., the height being about 50 mm; the width of the cardinal area is about 30 mm. at the preserved lower edge.

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa Japan, Vol. VI., No. 1, July, 1932]

The occurrence of *Lyttonia* was first made known by D. SATÔ(2), whose specimen I was entrusted to examine and describe.



Text-fig 1.
Cross section of the *Scacchinella* cf. *gigantea*: photographically reduced to natural size from the sketch made by SAKUMA.

Lyttonia and *Scacchinella* were found in a lower horizon of the *Fusulina*-limestone, called the Kasumi-zone, a light gray semi-crystalline limestone(3). A few other forms of which the characteristic features have not easily been recognized were collected together with these fossils. Among them a form of *Enteletes* was named *E. akasakensis* by the late Dr. OZAWA(4).

More recently, while I was examining various younger Palaeozoic fossils of our country these fossils came under my notice again and the presence of one other genus was ascertained. This genus is *Geyerella*.

The present paper describes, beside *Geyerella* sp., two species of the genus *Enteletes*. The preservation of these specimens is not favourable for a detailed description: the *Geyerella* can not be determined specifically, while the two species of *Enteletes* are named *E. minoensis*, nov. sp., and *E. Suessi* SCHELLWIEN, respectively. If OZAWA's species *E. akasakensis* is really an *Enteletes*, then this genus is represented by three species in the limestone of Kinsyzôan.

II. DESCRIPTION.

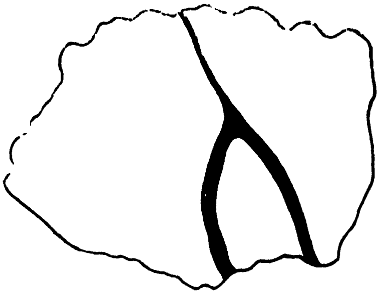
Geyerella sp.

(Pl. I., Fig. 1: Text-Fig. 2.)

This genus is represented by only one fragmentary specimen of a very high, rather cylindrical, ventral valve. It is characterized by a high and narrow delthyrium, which seems to have been covered by a convex pseudodeltidium; by the more or less flexuous, often bifurcating, rather sharp radial but somewhat irregular plications on the shell surface; and by the characteristic development of the dental plates.

The last point is the most important. The specimen was cut across nearly perpendicular to the area and the cut edge was polished. Here we see the two dental plates extended inwards, being parallel to each other for some distance, then converging rather abruptly to extend farther as a long, thin median septum (Text-fig. 1).

The specimen, being very incomplete, measurements of any kind are hardly possible. The height of the area may be assumed to be more than 45 mm.— possibly 50 mm. or more. The delthyrium is about 10 mm., very slightly narrowing toward the beak.



Text-fig. 2

A somewhat diagramatic sketch of a cut-edge of the *Geyerella* sp., to show the septal feature inside: enlarged.

As to the affinities of this fossil, *G. americana* GIRTY(5) should not be overlooked. In having an "elongate conical" ventral valve, which is ornamented with rather irregular plications, the Japanese and the American forms are alike.

The Japanese form, however, appears to be more cylindrical than the other. Either identification or distinction is not to be insisted upon.

Although GIRTY remarks that his American species resembles the Italian form—genotype —*G. gemmellaroi*(6), the much elongate form of the ventral valve of the former is an apparently distinctive feature.

Enteletes minoensis, nov. sp.

(Pl. II., Figs. 1-3.)

The specimen at hand is a fragment of a large and very strongly inflated dorsal valve. The following characters are observed: (a) a wide, shallow median depression, the walls of which are not concave, as is usually the case in this group of brachiopods, but are nearly flat in the transverse profile: consequently the bottom of the depression makes, in the central part, a longitudinal groove, inconspicuous but distinct (Pl. II., Fig. 1.): (b) the median depression zone is bounded on both sides by sharp ridges: (c) these ridges are accompanied by 3 or 4 ridges on the lateral surface of the valve; these lateral ridges augment at certain distances from the beak region, those nearer to the middle being earlier in appearance and more distinct: (d) all these radial ribs are most conspicuous in the visceral part of the valve, being weaker both toward the beak and the front (Pl. II., Fig. 2.): (e) the main radial ridges correspond to the crural septa inside (which fact shows the fossil to be a dorsal valve): (f) the anterior to antero-lateral margin shows a very strong zig-zag course, the median depression of the dorsal valve being pointed very acutely (Pl. II., Fig. 3.) and the other depressions also making sharp angles at the margin, the size and the sharpness of the angle decreasing toward the lateral ends: (g) hinge-line short, cardinal angle rounded.

From these observations, I consider the specimen to belong most probably to the genus *Enteletes*, and if so, it stands very close to *E. Kayseri* WAAG.(7) although the difference in size of the shells is very great.

Sometime ago, OZAWA(8) mentioned the occurrence of what he named *Enteletes akasakensis* from the same locality and in the same horizon. His diagnosis is by no means satisfactory and there is no positive evidence that it should be an *Enteletes*. Judging, however, from the pictures given by the author, some of the characteristic features of the specimen under consideration seem to be found in it too (see Pl. I., Fig. 3). But the general habit of OZAWA's new species appears quite different from that of the present one; the characteristic median depression in the dorsal valve of the latter, for instance, does not seem to be developed in OZAWA's specimen.

Enteletes Suessi SCHELLWIEN

(Pl. I., Fig. 2.)

1892. *E. Suessi*, SCHELLWIEN: Die Fauna des karnischen Fusulinenkalks, p. 37, pl. VII., Fig. 5. Palaeontographia XXXIX.

The only specimen of this species has been in my possession for several years. It is an incomplete specimen, with its anterior portion broken away and with the shell substance largely worn off. The specimen described by SCHELLWIEN is much better preserved and the diagnosis, though not lengthy, is very comprehensive. My specimen is just as large as SCHELLWIEN's. The very deep ventral valve has a flat and wide median depression which is bounded on both sides by diverging low ridges. Farther toward the edge the shell surface is slightly convex and, as a whole, slopes rather steeply down to the margin, having two less prominent and narrow ridges on each side: these ridges augment at a distance from the beak: the third pair, observed in the Alpine specimen, seems to have been on the lost part of the valve.

The dorsal valve is much less vaulted, with a wide but rather prominent median fold which corresponds to the median depression of the opposite valve: on both sides are rather conspicuous grooves, corresponding to the pair of foldings of the ventral valve. The outer slopes of these grooves are only very slightly inclined inwards, but beyond them the shell surface slopes down rather steeply.

The hinge-line is about half as long as the maximum breadth of the shell, sloping slightly down laterally: the cardinal angle is rounded. The area is filled with the matrix, but it is so far certain that the beaks are overhanging the hinge-line, if only slightly.

The surface of the shell is ornamented with fine, thread-like striations, which in my specimen are only sporadically preserved.

Several years ago, OZAWA, after having seen this and other fossils, including *Scacchinella* cf. *gigantea*, in my collection, mentioned in one of his papers⁽⁹⁾ the occurrence of what he named *Enteletes akasakensis*. His specimen is really different from SCHELLWIEN's but his conclusion that what I had named *E. Suessi* also is different from the SCHELLWIEN's is a casual one: *E. akasakensis* is different from either *E. minoensis*, as remarked above, or from the one under consideration.

III. GEOLOGICAL AGE.

Of the three species of *Reticularia* mentioned at the outset, *R. lineata* is the only species I found in the Kasumi zone of limestone: thus the

Brachiopod faunule of this zone comprises the following 7 species, namely, *Reticularia lineata, Lyttonia Richthofeni, Scacchinella* cf. *gigantea, Geyerella* sp., *Enteletes akasakensis, E. minoensis* and *E. Suessi,* the last five belonging to ORTHOTETINAE.

Concerning the geological age of *Geyerella,* SCHELLWIEN states at one place that it is "Permocarbon"(10), and at another, "ausschliesslich" Permian.(11) The "Middle of Capitan formation"(12) in which the American species described by GIRTY was found is lower Permian.

According to OZAWA's researches, the Kasumi zone of the *Fusulina*-Limestone of Kinsyô-zan, which is characterized by the occurrence in it of *Fusulina granum-avenae,* should be regarded as Lower Permian or Permo-Carboniferous.(13).

Thus, the *Lyttonia-Richthofenia* fauna of Japan, including the species mentioned above, has to be regarded as a whole as not younger than Earlier Permian.

(May 30, 1932.)

REFERENCES

(1) HAYASAKA, I.:—Jour. Geol. Soc. Tôkyô, No. 379. April, 1925.

(2) SATÔ, D.:—On *Lyttonia* recently discovered at Akasaka, prov. Mino (In Japanese). Jour. Geol. Soc. Tôkyô, No. 309, June, 1919.

(3) OZAWA, Y.:—Stratigraphical Studies of the *Fusulina*-Limestone of Akasaka, Province of Mino.:—Jour. Fac. Sci. Ser. II., Part 3, Tôkyô Imp. Univ. 1927.

(4) Ditto, p. 139.

(5) GIRTY, G. H.:—The Guadalupian Fauna. U. S. G. S. Prof. Paper 58, p. 204. pl. XI., fig. 2. 1908.

(6) SCHELLWIEN, E.:—Beiträge zur Systematik der Strophomeniden des oberen Palaeozoicum. N. Jahrb. für. Min. etc., Jahrg. 1900, I., pl. I., fig 1.

(7) WAAGEN, W.:—Salt-Range Fossils, Brachiopoda, p. 553. 1884.
SCHELLWIEN, E.:—Die Fauna des Karn. Fusulinenkalks, p. 35. pl. VII., fig 1. 2.
KAYSER, E.:—In RICHTHOFEN's China, IV., p. 179. pl. XXIV., fig. 2, 3, (*Syntrielasma hemiplicata* HALL), 1883.
FRECH, F.:—In RICHTHOFEN's China, V., p. 121. 1911.

(8) OZAWA, Y.:—l. c.

(9) OZAWA, Y.:—l. c.

(10) SCHELLWIEN, E.:—op. cit., p. 13.

(11) Ditto, p. 14.

(12) GIRTY, G. H.:—l. c.

(13) OZAWA, Y.:—op. cit., p. 134-136, etc.

EXPLANATION OF PLATES

(All figures in natural size)

PLATE I.

Fig. 1. *Geyerella* sp. A ventral valve: *a* - a lateral view, to show the characteristic longitudinal wrinkles or plications; *b* - the elongate cardinal area which is partly worn.

Fig. 2. *Enteletes Suessi*, SCHELLWIEN. *a* - As seen from the dorsal side; b - as seen from the beak end, the lower side of the figure being dorsal.

Fig. 3. "*Enteletes*" *akasakensis*, OZAWA. Reproduced from OZAWA, for the sake of comparison with *E. minoensis* described in this paper: *a* - "Diagonal view of dorsal valve showing sharp lateral-folds;" *b* - "Lateral view."

PLATE II.

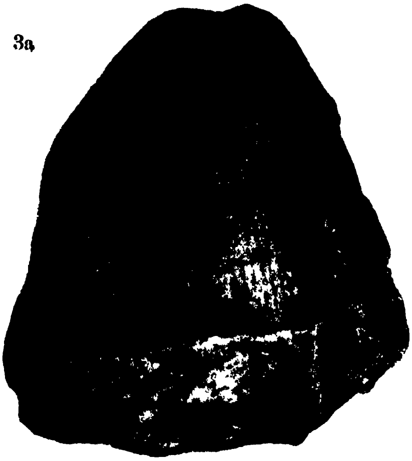
Enteletes minoensis n. sp.

Fig. 1. As seen antero-ventrally. Note the rather shallow median depression with a sharp longitudinal groove in the center. A zig-zag pattern of the anterior commissure is viewed obliquely.

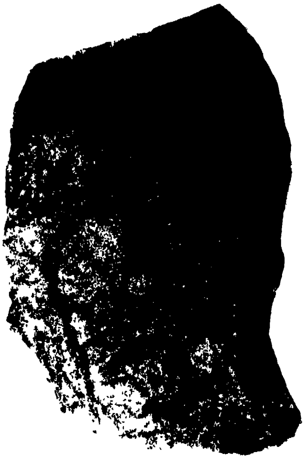
Fig. 2. Ventro-lateral view to show the development of the longitudinal wrinkles that are distinct only on the visceral part of the valve.

Fig. 3. An anterior part of the shell to show the zig-zag course of the anterior border, made distinct by means of tinting one side with black ink.

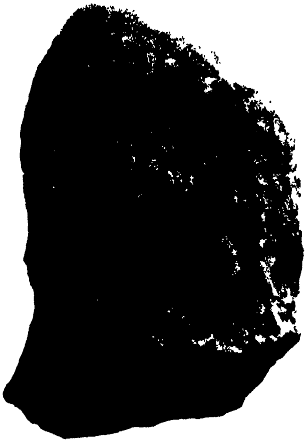
3a



1b

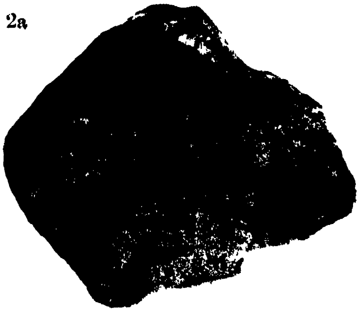


1a

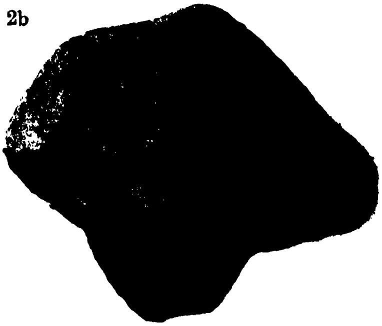


3b

2a



2b



ON THE CARBONIFEROUS BRACHIOPOD FAUNA FROM THE NABEYAMA REGION, TOTIGI PREFECTURE, JAPAN

(With 12 Plates and 6 Text-Figures)

By

Ichirô HAYASAKA

(Accepted for publication, Nov. 10, 1932)

CONTENTS

I. Introduction 9
II. Notes on the Locality of the Faunule 13
III. A Peculiarity of the Faunule 15
IV. Geological Age of the Faunule... 17
V. Description of Fossils 18
Bibliography 43

I. INTRODUCTION.

I. The material of the present paper consists not only of the small lot of brachiopods about which I made a short note several years ago,[1] but also a much larger collection of fossils from the same locality subsequently accumulated. Although some of the specimens of the older

---

1) Proc. Imp. Acad. II., No. 10, p. 551, 1926.

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VI, No. 2, January, 1933.]

collection are quite well preserved, most of them have the beak region broken off and the inner structures can hardly be observed. The determination of these fossils was based chiefly upon their external characters and consequently the note written was not to be regarded as final. The following is the list of the fanule given in the previous note:

Productus punctatus MARTIN
Meekella eximia EICHWALD *forma majuscula*
Orthotetes simensis TSCHERNYSCHEW
Schizophoria resupinata (MARTIN)
Spirifer aff. *rockymontanus* MARCOU
Reticularia lineata MARTIN

Soon after the paper was presented to the Imperial Academy I made a journey abroad and since then my palaeontological work on this material, as well as on others, had to be suspended until I got more or less settled recently in my present position in Taiwan. During this interruption, however, I have been able to enlarge the material of this brachiopod faunule. A number of very well preserved and almost complete specimens was supplied by Mr. IWAMOTO, a dealer in geological materials in Tôkyô, who, on my request and under my direction, visited the very locality where I made a collection several years ago. Among the many specimens there are several excellent ones of which the inner features have been examined by means of cutting and polishing. A few of them show some important characters even without any manipulations.

More recently, during the past summer, I had an opportunity of visiting the limestone region of Nabeyama for a short time. Several specimens were collected but as far as the collection is concerned, the excursion was not a successful one. It was ascertained, however, that the fossils under consideration are quite restricted in distribution and that at the locality where these fossils used to occur so abundantly they are seldom met with now.

Having these additional and much better specimens, I have been engaged in the careful revision of the faunule as a whole. The present paper is the outcome. The faunule consists of the following species:

Orthotichia japonica n. sp.
O. japonica subsp. *striata* n.
Enteletes acutiplicatus n. sp.
Streptorhynchus sp.
Meekella gigantea n. sp.
Orthotetina planoconvexa n. sp.
O. eusarkos subsp. *lata* n.
(?)*Daviesiella comoides* subsp.
Productus (*Echinoconchus*) *defensus* (THOMAS)
Spirifer acutiplicatus n. sp.
Squamularia sp.
Martinia sp.

II. The most attractive of the faunule is perhaps *Orthotichia japonica* which is represented altogether by a few scores of specimens. There having been previously only four specimens and those not complete, consequently the inner structures were not accessible, so this was erroneously referred to *Schizophoria resupinata.* Several specimens have been cut and polished since and it has been clearly seen that they have features characteristic of the genus *Orthotichia,* namely, the development in the ventral valve of a pair of long dental plates and a median septum.

It is very interesting that the Japanese species of *Orthotichia* is very conspicuous in size. As far as my knowledge is concerned, *Orthotichia japonica* may be the largest species of the genus hitherto known. It is not only this species that is extraordinarily large. *Meekella gigantea* and *Enteletes acutiplicatus* are also uncommonly large. In reality, *Meekella eximia,* with which the Japanese species was indentified, attains quite an enormous size but it does not seem to match the new Japanese species. A few specimens of *M. eximia* which occurred in the Upper Carboniferous of the Donetz basin, Russia, were purchased for comparison from Dr. KRANTZ of Bonn. None of them is comparable with *M. gigantea* in point of size, nor are the specimens figured by previous authors very much larger than these specimens. *Orthotetina eusarkos* var. *lata* also is conspicuously larger than the ordinary size of the species hitherto recorded.

The fact that the essential elements of this faunule are such abnormally large specimens is an interesting problem in the consideration of the palaeogeographical conditions of their life. To this we shall turn our attention again elsewhere.

On examining the newly added specimens of *Productus,* I have been able to decide that it is *Echinoconchus defensus* instead of *Prod. punctatus. Meekella gigantea* which is now represented in my collection by several good specimens and it is necessary to regard them as different from *M. eximia.* On the former occasion I possessed only one specimen, and, consequently, my idea was that the size of the shell might be an individual variation. It must be remembered that in the psychology of a palaeontologist a second occurrence of a certain example with some particular characters plays an unexpectedly important rôle in deciding the species, or perhaps even the genus, of an extraordinary fossil. The third and other examples we can expect to find in future.

What was believed to be *Orthotetes simensis* in my previous note has been proved to be *Streptorhynchus.* Several fragmentary specimens called *Reticularia lineata* have been added, and it has become evident that there are *Martinia* sp. and *Squamularia* sp. among them, though their specific determination is hardly possible.

The *Spirifer* which shows some affinity to *Sp. rockymontanus* "can not be identified with" the latter, as I remarked on the former occasion. It is not unlike the *Sp. trigonalis* of some authors, and it has recently been decided to be a new species which is more or less closely allied to *Sp. grandicostatus* M'COY. It is named *Sp. acutiplicatus.*

Orthotetina has been added to the faunule recently. Two species of this genus are described but each of them is represented by a single specimen. Further material is desired so that the details of the two species can be more firmly established. The species of *Orthotetina* in our fauna may represent the oldest occurence of the genus hitherto known.

In this place I want to express my thanks to Prof. S. NAKAMURA for the loan of several important palaeontological works for reference from the Library of the Geological Institute of the Kyôto Imperial University, as well as to Prof. H. YABE, by whose kind permission I have had access to the Library of the Geological Institute of the Tôhoku Imperial University, Sendai.

II. NOTES ON THE LOCALITY OF THE FAUNULE.

In my former paper, the locality was simply called Nabeyama but the occurrence of the fossil is restricted to two quarries at a place called Kadosawa in the western part of the village of Nabeyama.* These two localites work the same horizon or horizons of limestone exposed on both sides of the gorge running down from NW through Kadosawa toward the hamlet of Nabeyama. The region occupies the southern margin of the so-called Asio Mountains (Fig. 1) where the Palaeozoic Chichibu system forming the foundation of the volcanic group of Nikko exposes under a thin cover of pumice scoriae.

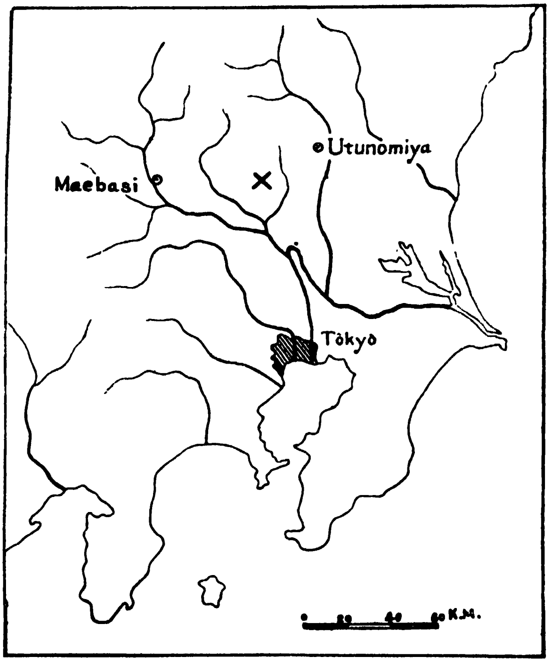


Fig. 1.

A chart indicating the position of the Nabeyama Region where the brachiopod faunule described in this paper is found.

The stratigraphy of the region under consideration has not been studied in detail. Prof. YABE once made a reconnaissance observation of the region with special attention to the distribution and the structural relations of the fossiliferous limestones.(1) In that paper the distribution of the limestones was plotted on a map, with notations of the trends of exposures observed by him. He intended to decide the geological horizon of the so-called *Fusulina-Limestone* which had been customarily considered as Carboniferous. The occurrence of *Fusulina*, which was identified with *F. japonica* in association with *Helicoprion*, was the basis of his theory that the limestone with this species of *Fusulina* is Permian in age.

---

* 栃木縣下都賀郡寺尾村大字鍋山字門澤

1) H. YABE:—On a Fusulina-Limestone with *Helicoprion* in Japan, 1903.

Although I visited the fossil locality and the neighbouring region twice, once in 1925 and then in the summer of this year, I had not time enough to make detailed observations of the geological and stratigraphical relations so as to be able to extend our knowledge.

As far as my observations in a very limited area around Kadosawa are concerned, the Palaeozoic Formation developed here consists of black slate with occasional sandstone beds, pale gray to grayish green chert which often contains radiolarian remains, and the limestone which is in part very rich in *Fusulina*. The field observations being quite limited in extent, it is not possible for me to establish the stratigraphical order of these rocks. The rock formation, as a whole, is more or less strongly disturbed by folding and faulting, and thus generalization of the stratigraphy of the region becomes more and more difficult. The geological relations remain as a problem of which the solution is left for the future.

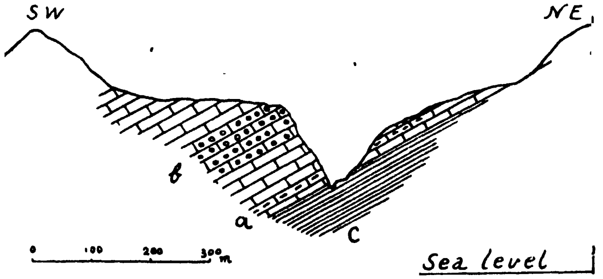


Fig. 2.

A geological profile across Kadosawa, slightly schematized: *a*. black bitunimous limestone with the brachiopod faunule under consideration; *b*. the limestone horizon especially rich in *Fusulina*; *c*. the non-calcareous series consisting of sandstones, slates and cherts.

The quarries at Kadosawa, where the fossils under consideration have been found, are in a relation shown in the profile inserted here (Fig. 2). The cliff on the southern side of the gorge is about 90 m. high, exposing a thick series of limestone, which is inclined about 30° toward SSW. The upper 70 m. is a reddish gray limestone, which is quite compact and hard. This limestone contains very abundant tests of *Fusulina* in the upper part. Below this is a black, bituminous zone, about 15 m. or a little more in thickness. It is in this bituminous part that the brachiopods have been preserved. The total thickness of 15 m. is not fossiliferous, however. It seems as if there is a horizon of a certain thickness in which the fossils abound.

At the exposure we do not recognize anything like an unconformity between the two kinds of limestones. The boundary between the gray and black limestones is, however, quite distinct.

On the northern wall of the gorge we see a part of the formation underlying the bituminous limestone. A series of sandstones, slates and cherts exposes here. The horizon with brachiopods on this side is exposed somewhat higher than on the opposite side.

The black bituminous limestone has been examined microscopically, but I have not been able to find even fragments of *Fusulina;* fragments of *Bigenerina* and *Tetrataxis*, as well as *Fistulipora*, are occasionally found.

Thus, as far as my brachiopod faunule is concerned, it does not occur together with the *Fusulina*, but it occurs in a horizon lower than that of *Fusulina*.

The *Fusulina* so abundantly found here is a species of the group of *F. japonica*, as has been believed. This species is, according to OZAWA, Lower Permian in age.

III. A PECULIARITY OF THE FAUNULE.

As has been mentioned above, some of the elements of the fauna under consideration are extraordinarily large in size. *Orthotichia japonica*, *Meekella gigantea*, *Orthotetina eusarkos lata* and *Enteletes acutiplicatus* may be mentioned as examples.

Among the late Palaeozoic marine invertebrates I have been examining, there is at least another fauna which contains conspicuously large shells. It is the molluscan fauna from the Fusulina-limestone series of Kinsyôzan, Akasaka-mati, Gihu Prefecture. *Pleurotomaria*, *Naticopsis*, *Bellerophon* and several other genera among the gastropods are represented by the undescribed species of extraordinary size, while *Solenomorpha elegantissima* HAYASAKA[1] is a very large species which perhaps is matchless in point of size among the late Palaeozoic pelecypods.

It is very interesting to see that such enormous forms of marine invertebrates occur, both at Kinsyôzan and Kadosawa, in the black, bituminous parts of the limestones. It may be said that the physical condition under which such bituminous limestones was deposited had an influence upon the growth of the shell-bearing organisms living therein, although it is not possible to explain what the actual relations could have been.

In connection with this problem, let us turn to the concluding chapter of Prof. GRABAU'S "The Permian of Mongolia"[2] in which the author expresses his opinion about the "dominant dwarf character" of the fauna of "the Jisu Honguer limestone." According to his observations on the recent marine fauna of Pechili Bay, where the salinity of the sea water is decreased by the rivers flowing in, there are several molluscs that are more minute in size than the equivalent normal forms living outside the bay. GRABAU considers that the dwarfness of some of the Permian brachiopods is due to the same cause, that is, the decreased or subnormal salinity of the sea water of the Mongolian geosyncline.

It is generally accepted that the salinity of the water, in a wider sense, affects the growth of the organisms living therein. If GRABAU'S theory be strictly adhered to and if the reverse also is true, then the fauna containing abnormally large specimens must be regarded as representing an increased or over-normal salinity of the sea in which the fauna lived. Concerning the Mongolian Permian brachiopods, GRABAU remarks that some of the fossils, including *Spirifer*, do not seem to have been affected. In my faunule, too, the Spiriferids are of normal size.

At the present the marine molluscs of the southern seas tend to develop large and heavy shells. This may be the result of multiple causes the analysis of which may throw some light upon the solution of the problem. However, it seems certain that large, heavy molluscs live in coral seas where carbonate of lime seems to be abundant in the sea water.

---

1) Sci. Rep. Tôhoku Imp. Univ., 2nd ser., Vol. VIII, No. 2, 1925.

2) Natural History of Central Asia, Vol. IV, Chap. XX, 1931.

In every way the physical environment of the Mongolian Permian and the parts of the Japanese Carbono-Permian seas seem to have been the reverse.

IV. GEOLOGICAL AGE OF THE FAUNULE.

As has been remarked in the preceding pages, the brachiopod faunule occurs in a horizon below the one with *Fusulina.* It seems certain that there is a faunal discontinuity between the Fusulina-limestone above and the brachiopod horizon below.

The Fusulina-limestone overlying the brachiopod horizon at Kadosawa is unfortunately represented by a few fragments of the rock and the identification of the species of the foraminifer has not been easy. In a place called Yamasuga,* near the village of Kuzû,** *Fusulina kaerimizensis* OZAWA[1] is very abundantly found. It is naturally washed out and it is very easily picked up at the foot of the small cliff where the limestone exposes. The *Fusulina* of Kadosawa may also be this species, as I considered it to be on the former occasion.

In every way *Fusulina japonica* is Lower Permian and *Fusulina kaerimizensis* is "Uralian-Permian" in geological age.

Turning to the brachiopods themselves, all of the genera described in this paper range from the Permian down to the Carboniferous, a few of them showing characters suggesting their being even Visean. *Streptorhynchus, Orthotetina* and *Martinia* are known to range from the Lower Carboniferous to Permian, while *Orthotichia, Enteletes, Meekella* and *Squamularia* are Upper Carboniferous to Permian in range. *Daviesiella,* of which the determination is not quite certain, may be put aside, but *Productus* (*Echinoconchus*) *defensus* is Visean in Britain. *Spirifer acutiplicatus,* perhaps, belongs to the group of *Sp. trigonalis* in a wider sense, thus suggesting its being Carboniferous, but not Permian, in age. The fauna, as a whole, is not younger, if not older, than Uralian.

Although most of the species of the fauna are new ones, the characteristic assemblage of the genera seems to prove that these species represent the older part of the range of time in which the individual genus survived. The generic assemblage resembles in no small degree that of the brachiopod genera in the well known Moscovian faunas of Russia. Thus our fauna may go as far back as to Moscovian in age. The species, as a whole, differ from those hitherto known in the Permian, either of our country or of the countries around. Perhaps *Orthotetina eusarkos lata* may look as if it shows a close relation between this and the Permian faunas of Loping[1] or Mongolia[2] but the Japanese fossil, which is represented by only a single specimen, is rather distantly related to *O. eusarkos*. The subspecific position given to it is rather a provisional one, the ultimate decision being left for a future discovery of more examples.

---

* 山菅 ** 葛生

[1] Jour. Coll. Sci. Imp. Univ. Tôkyô, Vol. XLV, Art. 6, p. 31, 1925.

Beside brachiopods and *Fusulina*, I have a specimen of a small piece of gray limestone which contains a fragment of a compound anthozoa, which I think is a species of *Lonsdaleia* in a wider sense. This was presented to me by Mr. T. SIKAMA, who wrote to me that he obtained it at Minowa,* south of Kadosawa. A detailed description is not possible. Another coral, which I believe is a *Waagenophyllum*, was obtained by me at the quarry of Wada,** near Kuzû. The stratigraphical relation of the limestone of this locality and that of Kadosawa-Minowa is not easy to decide.

V. DESCRIPTION OF FOSSILS.

RHIPIDOMELLIDAE SCHUCHERT

ORTHOTICHIA HALL & CLARKE

Orthotichia is regarded by palaeontologists as either a subgenus of *Schizophoria* or another genus very closely allied to the latter. It really has all the essential features of *Schizophoria*, but is clearly distinguished from the latter, as well as from any other apparently allied forms, by

---

1) FRECH :—RICHTHOFEN's China, V, p. 123, pl. 26, Fig. 1, 1911.
2) GRABAU :—The Permian of Mongolia, p. 253, pl. XXIV, Fig. 7, 1931.
* 箕輪 ** 和田

developing a pair of long dental plates and a median septum in the ventral valve. As long as stress is laid upon structures inside in classifying externally resembling forms of brachiopoda, *Orthotichia* should be considered as a form (not necessarily a genus in the strict sense of the term) having an isolated position in the systematic of the RHIPIDOMELLIDAE.

The Japanese form under consideration here was provisionally called by me *Schizophoria resupinata* (MARTIN) DAVIDSON in a preliminary report published a few years ago.[1] At that time there were four specimens at my disposal, all in rather an unfavourable state of preservation. It was not possible for me to examine the inner structural features because the ventral valves are mostly broken off. Even the form of the valves was not very well recognized, the higher dorsal beak of one of the specimen having been suspected to be rather an exceptional, or possibly a pathological, form of the ordinary *Schizophoria resupinata*. Recently, however, I could collect many more specimens, some of which are very excellently preserved, so that the structures inside the valves have been observed in detail by means of serial sectioning of some of the specimens. The development of the long dental plates, and with a median septum in between, the decisive characteristic feature of *Orthotichia*, has been very clearly exhibited on the polished surfaces across the beak region of ventral valves (Fig. 3).

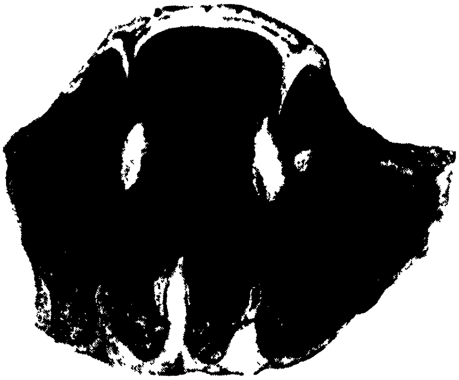


Fig. 3.

Orthotichia japonica: a cut-edge across the umbonal region showing the characteristic septal structure. Photographic reduction of a sketch by SAKUMA.

The most characteristic of the Japanese fossils is the decided largeness of the valves, though there are a few smaller specimens at hand. The specific name *japonica* is proposed for this fossil and its diagnosis follows.

---

1) Proc. Imp. Acad. II., No. 10, pp. 551-553, 1926.

Orthotichia japonica HAYASAKA

Pl. III, Fig. 1; Pl. IV; Pl. V; Pl. VI, Fig. 1; Text-Fig. 3.

1926. *Schizophoria resupinata* (non MARTIN, non DAVIDSON), HAYASAKA:—On a New Carboniferous Brachiopod Fauna from the Ashio Mountains, Japan. Proc. Imp. Acad., 2, No. 10, p. 552.

1932. *Orthotichia japonica*, HAYASAKA:—An Upper Carb. Fauna of Japan (Japanese). Jour. Geol. Soc. Tôkyô, XXXIX, No. 468, p. 548, Pl. V., Fig. 3.

EXTERNAL FEATURES: Outline hemispherical, wider than long; the maximum width is in the middle.

Ventral valve is small and very flatly conical in the umbonal region, the shell being more or less concave anteriorly and laterally; the high triangular cardinal area is either erect or reclined. The valve is slightly depressed medially so as to form, in some of the specimens, a median sinus, which only slightly influences the anterior commissure.

Dorsal valve is much larger and is almost hemispherically inflated, with a strongly vaulted umbonal region, the beak overhanging the hinge-line. Dorsal area is only slightly developed and in some of the specimens even not observed; it is a very low triangle. Median vaulting in correspondence with the median flattening of the other valve is hardly recognized.

Surface of the shell is ornamented with numerous fine thread-like radial striae, with much stronger ones distributed among them at more or less regular intervals. The latter are not continuous but suddenly terminate at an irregular distance from the beak, with more or less elongate hollows of rather irregular form. In some of the strongly weathered specimens only these hollows are seen on the surface (Fig. 1, Pl. III). Concentric growth-wrinkles are not usually distinct in the umbonal region; they are very strongly developed in the anterior half, and especially in the marginal region of the shells, sometimes looking even more or less scaly.

Hinge-line is straight, about one half as long as the maximum width of the shell. Ventral area is 1/4—1/5 as high as the hinge-line and is laterally striate. Delthyrium is narrow and appears to be closed; deltidial plates are not preserved in the specimens at my disposal. Dorsal area, when well developed, is about 1/10—1/15 of the hinge-line; further details not exhibited.

INNER FEATURES: In the umbonal region of the ventral valve the septal plates supporting the hinge plates are well developed, thick and quite wide within a short distance from the beak. They are divergent, and get rather suddenly shorter toward the front. In specimens of a moderate size (85 mm. wide) the hinge plates are about 25–30 mm. long antero-posteriorly and the distance between them at their distal end is about 20 mm. In the ventral valve there are two well developed dental plates which are quite long and a median septum in between. The median septum is short and rather inconspicuous just below the beak, where dental plates are very long, but it gets longer, anteriorly, while on the contrary, dental plates become shorter. In some of the specimens in which the interior of the beak region is weathered out, the median septum is nothing but a very low ridge on the inner surface of the shell, whereas the dental plates connect the visceral portion of the shell and the hinge-line. In another specimen, estimated to measure about 70 mm. in width, the dental plates and the median septum are almost equal in length at a distance of about 25 mm. from the beak; about 7 or 8 mm. anteriorly all the three elements are much shorter, and the median septum appears to split into two low ridges.

DIMENSIONS: Of more than a score of specimens, the following measurements of the better preserved ones are given (see the Table below).

Specimens / Dimensions		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Length		94 mm	83 mm	ca. 88 mm	66 mm	78 mm	81 mm
Length on Curvature	Ventral	160	130	ca.130	ca.120	ca.130	148
	Dorsal	80	80	ca. 85	ca. 57	55	ca. 73
Width		97	96	99	82	90	ca. 92
Thickness		61	51	50	48	ca. 50	53
Hinge-line		45	ca. 45	54	45	ca. 50	ca. 38
Area-height	Ventral	—	ca. 15	15	ca. 13	13	ca. 13
	Dorsal	—	—	ca. 6	—	4	

REMARKS AND AFFINITIES: As is seen from the above measurements, the Japanese specimens here described are unique in their enormous size as compared with any of the known species of the genus. Moreover, the erect or forwardly inclined ventral area, the much higher dorsal beak and the almost straight anterior margin must be regarded as characteristics of the new species.

Dalmanella Frechi FLIEGEL[1] from Padang, Sumatra, seems to resemble the present Japanese species, especially in such features as the ventral valve being smaller than the dorsal, and the size being quite large as compared with the other species of this group of brachiopoda. Concerning the internal features, FLIEGEL writes that "in each valve a median septum as well as two laterally diverging septa are observed." If this is really the case, then there is this difference that the Sumatran species possesses, in addition to the inner structures of the Japanese one, a median sinus of the dorsal valve.

Orthotichia japonica subsp. **striata** n.

Pl. VII, Fig. 1.

1932. *Orthotichia japonica* subsp. n., HAYASAKA:—An Upper Carb. Brachiopod Fauna of Japan (Japanese), p. 548.

Among the many specimens of *O. japonica* there are two which are quite different from the others. The surface ornamentation consists in thin but very distinct striae or lirae that are continuous from the beak to the margin, increasing anteriorly by interpolation at various distances from the beak. In the second place, the ventral valve seems to be much more flattened or shallower, the area being far more strongly reclined.

One of the specimens is a dorsal valve with the major part of the strongly reclined ventral area attached. The size of the specimen is just about the average of *O. japonica*. The second specimen is a little smaller than the first. In it, however, the ventral valve is not entirely lost and the very slight elevation of its umbonal region is suggested by the remaining marginal portion of its valve.

---

1) Palaeontographica XLVIII, p. 97, pl. VI, Fig. 10.

ENTELETES FISCHER

Enteletes acutiplicatus nov. sp.

Pl. VIII, Fig. 1.

Of this species there are only three specimens that are not complete shells. One of them, however, is comparatively well preserved with only the beak region of the ventral valve broken off. On the fracture surface, the arrangement of the septal elements characteristic of the genus is very distinctly exposed, a pair of very long, nearly parallel, thin dental plates and an equally thin median septum in between, which is about half as long as the former.

The species may be diagnosed as follows:

Shell large, almost globose, measuring 36 mm., 39 mm. and ca. 34 mm. in length, width and thickness or height, respectively. Dorsal valve is larger and more convex than the ventral one. Plications are very few in number, only five being counted in the dorsal valve, and six in the ventral, all being very acute, augmenting at about 10 mm. from the beak, and forming a very sharp and deep zig-zag pattern of the suture in the front. The median fold in the dorsal valve and the corresponding median angular sinus or depression are very wide, measuring ca. 9.5 mm. at the anterior margin. A pair of the first lateral ridges of the dorsal valve is half as wide and much lower; the second lateral pair is rather low and the apex is rather rounded, instead of having sharp edges. The plications of the ventral valve are, as a whole, lower, but the sharpness of the ridges is just like that of the dorsal radial plications; the external pair is rudimentary in appearance, being recognized as such only along the antero-lateral commissure. The first and the second inner pairs are almost equal in strength. The surface of the shell is ornamented with zig-zag growth lines, running parallel to the anterior commissure, and becoming more or less lamellose in the marginal part of the valves.

Remarks and Affinities: As far as I am aware, *Enteletes plattsmouthensis* Newell[1] is the species most closely allied to the present one.

---

1) Norman D. Newell:—New Schizophoriidae and a Trilobite from the Kansas Pennsylvanian, p. 262, 1931.

Although there is a difference in the size of the shell of the two species, the habit of growth of the two is almost alike. The only difference which may be taken as being of specific value is the difference of the number of plications. In the American species there are three to four pairs of them on each side of the dorsal median fold, while there are only two pairs in the Japanese species under consideration. The two other specimens at hand, though much more incomplete in preservation, develop the same number of plications as in the type specimen.

Among the Salt-Range species *Enteletes latesinuatus* WAAGEN[1] and *Enteletes ferrugineus* WAAGEN[2] look somewhat like the present Japanese species. The former two are characterised by having very few plications just as in the last. However, owing to the fact that the ventral valve, instead of the dorsal valve, develops a median fold, these and the few other Salt-Range forms are grouped by KING under the generic name of *Parenteletes.*[3] *Parenteletes* is represented by *P. cooperi* KING from the Glass Mountains of Texas. More recently SCHUCHERT and COOPER established another genus, *Enteletina,*[4] taking "*Enteletes*" *latesinuatus* as the genotype. According to these latter authors, *Enteletina* is "externally like *Parenteletes* but internally like *Enteletes.*" In other words, in *Enteletina* a median septum develops between the dental plates while in *Parenteletes* it does not develop.

Whatever the case may be, we can easily recogize the difference in the mode of development of plications in "*Enteletes*" *latesinautus* and in *Enteletes acutiplicatus.* In the former, in accordance with its broad dorsal sinus, the ventral median fold is a wide and rather low ridge while in the latter they are both very acute. In this character "*Enteletes*" *ferrugineus* looks much more like *Enteletes acutiplicatus* than "*Enteletes*" *latesinuatus.* It is interesting to see that the acute-plicate species "*E.*"

---

1) WAAGEN:—Salt-Range Fossils, p. 559, pl. LVII, Figs. 4, 5, 6.

2) *Ditto*:—p. 556, pl. LVII, Figs. 7, 8.

3) ROBERT EVANS KING:—The Geology of the Glass Mountains, Texas: II. Faunal Summary and Correlation of the Pernian Formations with Description of Brachiopoda, p. 48, 1930.

4) CHARLES SCHUCHERT and G. ARTHUR COOPER:—Synopsis of the Brachiopod Genera of the Suborders Orthoidea and Pentameroidea, with Notes on the Telotremata, p. 247, 1931.

ferrugineus is regarded by WAAGEN as the oldest of the Salt-Range species of *Enteletes*[1]. In *Parenteletes cooperi* KING of the Glass Mountains we see the plications that are of a similar appearance to those of the Japanese species. This species occurs in the Lower Gaptank formation which is considered to be about the middle Pennsylvanian (Wewoka),[2] although it is more abundant in the lower part of the Permian Wolfcamp formation.[3]

STROPHOMENIDAE KING

STREPTORHYUCHUS KING

Streptorhynchus sp.

Pl. IX, Figs. 1 & 2.

There are four fragmentary specimens of *Streptorhynchus* in my collection. Unfortunately, none of them is a good enough specimen to allow a specific determination. The beak region is broken off from each of them, leaving only a part of the cardinal area. It is seen in one of the specimens that the beak is to some extent twisted. The area appears to be quite high with a rather narrow delthyrium in the middle. The area is not so wide as the length of the hinge-line, which is much shorter than the maximum breadth of the shell. By means of polishing the umbonal end of the ventral valve, it is ascertained that there is no septal structure inside.

The shell is moderate in size, almost rounded in outline, measuring about 40 mm. in width. Both the valves are convex, the dorsal one being a little more inflated. No median fold nor median depression. Surface of the shell is covered with fine, thread-like striae which increase anteriorly by interpolation. Radial undulation is slightly developed on the surface. Concentric growth-wrinkles are frequent in the anterior half of the shell; they are very distinct toward the margin.

---

1) W. WAAGEN:—*op. cit.*, p. 557.

2) PHILIP BURKE KING:—The Geology of the Glass Mountains, Texas, I: Descriptive Geology, pp. 43-49, 1930.

3) *Ditto*, pp. 52-57.

MEEKELLA WHITE & ST. JOHN

The genus *Meekella*, as has been laid stress upon by GIRTY, is distinguished from the allied forms of brachiopods by "its plicated surface and its long, nearly parallel dental plates." There is no development of a median septum in its ventral valve. The Japanese specimens under consideration were provisionally called *M. eximia forma majuscula* in my preliminary report, without my examining the characteristic features of the dental plates and other inner structures, because I then possessed only one rather incomplete example. Having recently obtained two more comparatively well preserved specimens, I have been able to make observations on the development of the dental plates by cutting and polishing the specimens (Fig. 4). The Japanese fossils really belong to the genus *Meekella*, of which *M. eximia* is a very close ally. However, the extraordinarily large size of the shell and a few other characteristic features seem to suggest their being a new species.

The specific characters are described as follows.

Meekella gigantea HAYASAKA

Pl. VI, Fig. 2; Pl. IX, Fig. 4; Pl. X; Pl. XI; Pl. XII,
Fig. 1; Pl. IX, Fig. 3; Text-Fig. 4.

1926. *Meekela eximia forma majuscula*, HAYASAKA:—On a New Carb. Brach. Fauna from the Ashio Mountains, Japan. Proc. Imp. Acad. II., No. 10, p. 552.

1932. *Meekella gigantea*, HAYASAKA:—An Upper Carb. Brachiopod Fauna of Japan (Japanese), p. 548, Pl. V., Fig. 1.

Shell very large, widest in the middle. Ventral valve moderately high, umbonal region abruptly tapering into a rather pointed beak with a high, triangular area beneath, which is inclined over the hinge-line and, to some extent, the dorsal beak. Area very well defined, slightly concave antero-posteriorly, laterally striated, with a distinct pseudodeltidium in the center. Pseudodeltidium is marked with a narrow median ridge, with almost equally wide depressed parts on both sides, which seems to indicate the position of the pedicle; in the section it is observed that this ridge corresponds to the position where the inner surface of the dental plates converge; the lateral margins of the pseudodeltidium correspond to the axial plane of the dental plates, the outer surface of the latter lying a little farther beyond (Text-fig. 4: Fig. 4, Pl. IX). Dental plates long, slightly convergent downward and forward, looking almost parallel on certain fracture surfaces. They are not so clearly parallel to each other as in the typical forms of *Meekella*, but they do not unite before reaching the shell wall; thus the structure is, to a certain measure, intermediate between the two genera *Geyerella* and *Meekella* (Fig. 4, Pl. IX; Fig. b, Pl. X.) Dorsal valve transverse, oval in outline, moderately convex, with more or less inflated but only slightly prominent beak; area beneath is low and linear.

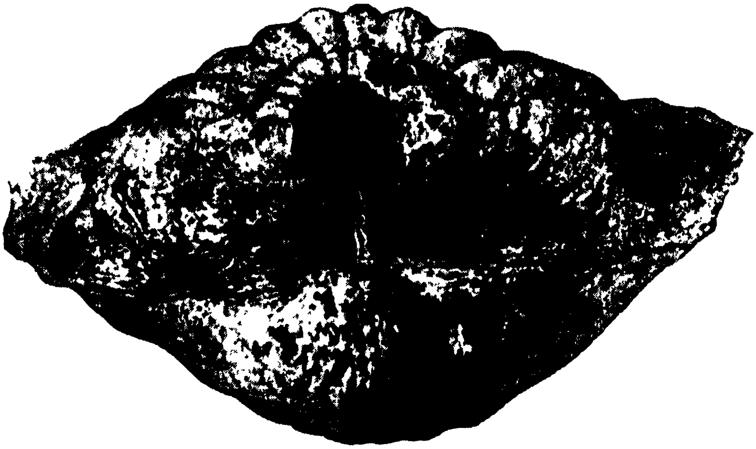


Fig. 4.

A sketch of *Meekella gigantea* made by SAKUMA, photographically reduced. On the polished cut-edge of the ventral beak sub-parallel dental plates are shown. The photograph of this is given on Pl. XII. (Fig. 1).

Surface of the ventral valve ornamented with very coarse radial ribs or plications that are well defined in the middle but become less distinct laterally. They appear at a very little distance from the beak, and number 12, some of them showing a tendency toward bifurcating anteriorly; the interspaces or sulci are much narrower, and sharp, deeper toward the middle of the valves. Relative width of plications and interspaces are reverse in the dorsal valve. Much less distinct concentric growth-wrinkles are present, being numerous and conspicuous in the anterior border of the valves, more or less scaly. All over the surface, both on the plications and in the interspaces, minute, thread-like lirae develop. Lirae and plications not parallel.

DIMENSIONS: All the three specimens being deformed to some degree, the measurements are not so accurate as could be desired but the order of magnitude can be understood from the following:

	No. 1	No. 2	No. 3
Length	ca. 100 mm.	ca. 92 mm.	ca. 95 mm.
Width	127	ca. 110	ca. 115
Depth (or Thickness)	ca. 90	62	
Hinge-line	ca. 82	ca. 60	ca. 75
Area-height (Ventral)	ca. 40	ca. 23	
Area-height (Dorsal)	4	3	
Pseudodeltidium—Apical Angle	26°	28°	

Of these three specimens, No. 1 has its anterior portion depressed, No. 2 is more or less compressed longitudinally and No. 3 is compressed ventrodorsally.

OBSERVATIONS: That this species very much resembles *M. eximia* EICHWALD[1] is not to be doubted. However, it seems that the present species attains a much larger size than the latter, the larger size not being a mere individual chance, which possibility had been in my mind until I got additional examples. YAKOWLEW (*l. c.*) also described quite a large example of *M. eximia* but it still is hardly 50 mm. in length. *Orthis eximia* of TRAUTSCHOLD is said to attain a large size (*op. cit*, p. 346) but the specimens described by this author do not differ much from those of TSCHERNYSCHEW. As far, however, as the size and the habit of growth of the specimens are concerned, the present Japanese fossils appear

---

1) TRAUTSCHOLD:—Die Kalkbrüche v. Mjatschkowa, p. 346 (*Orthis eximia*). 1878: TSCHERNYSCHEW:—Die oberkarbon. Brachiopoden d. Ural u. d. Timan, p. 213 & 582, pl. XXIV, Fig. 5; Pl. LI, Fig. 13, 1902: YAKOWLEW:—Die Fauna d. ober. Abt. der paläoz. Abl. in Donez-Bassin, III, Brachiopoden, p. 2 & 29, pl. I, Figs. 1-9; Pl. II, Figs. 1-3, Mém. Com. Géol. Nouv. Sér. Livr. 79, 1912. This species was considered by YAKOWLEW as identical with the American species *M. striatocostata* COX; and four species of the Trogkofelschichten, as well as *M. uncitoides* TSCHERN. are regarded as synonymous, too.

to represent senile forms of the typically Russian species. Another possibility is the particular ecological condition which may have prevailed while these fossils were living in this part of the world.

In point of size and surface sculpture, *M. timanica* TSCHERNYSCHEW¹⁾ also must not escape our considerations as comparable, though it does not equal the Japanese form. Moreover, the deltidium or pseudodeltidium of the former is characterized by its being unequally three-fold, the median convex part being very much wider than the two lateral depressed parts; in the Japanese fossils the pseudodeltidium is divided into three almost equal widths. Neither the forms of the shells are similar in the two species, the Japanese one being a little more inflated.

Turning again to *M. eximia*, TRAUTSCHOLD's figure (Fig. 13b, *op. cit.*) shows that the cardinal area of the ventral valve is not so strongly convex as in the Japanese species, although it is by no means flat.

The radial plications are of the same type in both the species *gigantea* and *eximia*, but they are in the former distinct in the umbonal region of the valves (Fig. 4, Pl. IX), where, in the latter, they do not develop.

According to YAKOWLEW, who admits a rather wide range of variation of *M. eximia*, there are two types in this species,²⁾ namely, (1) the specimens that have a wider ventral valve with more obtuse umbonal angle in which the radial plications are more strongly developed, and (2) those that have a more elongate ventral valve with more acute umbonal angle in which the radial plications are entirely absent, or only very indistinctly developed. The Japanese specimens represent the first group, though they belong to a different species.

M. eximia is one of the important upper Carboniferous index fossils in Europe, as well, perhaps, as in North America, provided that *M. striatocostata* is identical with the Russian species.

Another species to be compared with the present one is a recently established Permian species of the Glass Mountains, Texas, namely,

---

1) *Op. cit.*, p. 216 & 585, Pl. XXV, Fig. 4.

2) YAKOWLEW:—*op. cit.*, p. 29.

Meekella grandis KING.1) Judging from the diagnosis, as well as from the pictures given by KING, this species seems to be the most closely allied to the Japanese species. The habit of the growth of the shells and the development of plications on the shell surface appear to be quite alike in these two species. However, the Glass Mountains species differs from the other by the "low convexity of both valves." Moreover, there is a tendency that the plications on the shell surface are more numerous in the former than in the latter. These are the most marked differences between the two, if the difference in the size of shells be neglected. *Meekella grandis* is Permian in age, being found in the Wolfcamp, Hess and Leonard formations.2)

A NOTE ON ORTHOTETINA SCHELLWIEN

The name *Orthotetina* was suggested by SCHELLWIEN3) to include those "*Orthotetes*" in which dental plates are long, closely set and parallel or even convergent, instead of being rather short and divergent in "*Orthotetes*" *s. s.* However, SCHELLWIEN does not seem to have laid very much stress upon this character of dental plates; neither does he seem to have claimed the generic standing of his "*Orthotetina*", because he has never used it again, as GIRTY pointed out.4) GIRTY's opinion is that *Orthotetina* should be a subgenus of *Meekella*, because the only difference in these two is the absence and development, respectively, of plications on the shell surface. This was adopted by SCHUCHERT, who briefly characterises *Orthotetina* as being "like *Meekella*, but without costae."5) In 1930, KING6) diagnosed the genus *Orthotetina* briefly but very distinctly, but that author does not seem to have been very strongly convinced of the generic rank of *Orthotetina*, based on the observation of

---

1) ROBERT EVANS KING:—The Geology of the Glass Mountains, Texas, II. Faunal Summary and Correlation of the Permian Formations, etc, p. 54, Pl. VI, Figs. 5-7, 1930.

2) PHILIP BURKE KING:—The Geology of the Glass Mountains, Texas, I. Descriptive Geology, 1930.

3) SCHELLWIEN:—Neues Jahrb. f. Min. etc. I, p. 8, 13, 1900.

4) GIRTY:—Gudalupian Fauna, p. 209, 1908.

5) EASTMAN:—Text-Book of Palaeontology I, p. 387, 1913.

6) ROBERT EVANS KING:—The Geology of the Glass Mountains, Texas, II, p. 52.

THOMAS[1] and others who regard it as of heterogenus origin. GRABAU,[2] on the contrary, considers that there is no reason to deny the generic rank, as GIRTY did.

KING,[3] in his work cited above, proposed a new generic name *Orthotetella* to denote a similar brachiopod in which the dental plates or "the deltyrial supporting plates are produced foreward and inward, joining to form a cone or spondylium of subcircular cross-section, its apex at the beak." We see that in *Meekella* and *Orthotetina* the dental plates are often more or less convergent. If this convergence takes place so that they meet each other on the bottom of the valve, it is a feature characteristic of *Orthotetella.* If the dental plates, after having united, extend farther anteriorly, it is the structure characteristic of *Orthotetes.* Thus, as KING observes, *Orthotetella* is "one of the most highly specialized genera of the ORTHOTETINAE." It seems to me that *Orthotetina* occupies a position intermediate between *Orthotetes* and *Orthotetella,* as far as these genera are considered with respect to the structural features of the dental plates. As to the relation between *Orthotetina* and *Meekella,* GRABAU'S remarks may be considered as conclusive.[4]

Whatever may be the systematic position of *Orthotetina,* it appears so far certain that it represents Uppermost Carboniferous and Permian. SCHELLWIEN observes that it seems to be limited to the highest horizon of the Upper Carboniferous and Permian. The Guadalupian species was found in the "middle of Capitan formation" which is lower Permian. The Glass Mountains species, *O. mutabilis* KING occurred in the Uppermost Carboniferous (Gaptank formation) and in the Lowermost Permian (Wolfcamp formation). The Mongolian occurrence mentioned by GRABAU includes 3 species; they are found in three different horizons of the middle part of the Mongolian Permian—the Jisu Honguer formation. Two of them have equivalents in the Permian of Southern China.

In my collection I have two specimens of *Orthotetina* that have been

---

1) THOMAS:—Mem. Geol. Survey of Great Britain, Pol., Vol. 1, pt. 2, pp. 91-92, 1910. This work has not been accessible to me.

2) GRAUBAU:—The Permian of Mongolia, p. 250, 1931.

3) ROBERT EVANS KING:—*op. cit.*, p. 51.

4) GRABAU:—*op. cit.*, p. 251.

added quite recently. These two are quite different in appearance, the one being much larger than the other. The larger specimen has convex valves while the smaller one has a plano-concave ventral and convex dorsal valves. Both these specimens show that the dental plates are quite strong and long, being more or less convergent. The smaller specimen appear to be not very far from the Chinese species *O. ruber*, while the other one may be another species, being rather extraordinarily large as a species of this genus; it looks somewhat allied to *O. eusarkos.*

Orthotetina planoconvexa n. sp.

Pl. VII, Fig. 2; Text-Fig. 5.

Shell is moderate in size; ventral valve is plano-concave with a pointed and reclined beak, while the opposite valve is rather strongly convex. The maximum breadth of the shell lies in the middle, the hinge-line being half as long. Ventral cardinal area high, with a large delthyrium in the middle; the area makes an angle of about 120° with the plane of the shell commissure. Dorsal valve has a very small area which is hardly recognized; beak rounded. Surface of the valves is ornamented with fine radial striae, not showing any tendency toward the formation of plications; concentric growth-wrinkles are found developing in the anterior part of the valves.

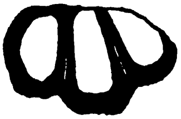


Fig. 5.
Cut-edge of the ventral beak of *Orthotetina planoconvexa*, showing the dental plates. ca. ×4.5.

By cutting and polishing the pointed end of the ventral valve we clearly see a pair of dental plates which are long and a little converging toward the bottom of the valve (Fig. 5).

Dimensions: The specimen is strongly deformed and its real dimensions can not be measured. The length is estimated to be something about 45 mm., while the width may be about 55 m. or a little more; the thickuess of the visceral part may exceed 25 mm.; the hinge-line (or the base of the area) measures about 28 mm., its height being about 15 mm.; the base of the delthyrium, 8 mm.

---

1) Grabau:—*op. cit.*, p. 30.

OBSERVATIONS: As has been remarked above, this species somewhat resembles *O. ruber* (FRECH).[1] In the latter, the ventral valve is described by GRABAU to be plano-convex; while in the former it is rather plano-concave. In this respect FRECH's original pictures almost coincide with the Japanese species under consideration. However, the hinge-line of the Chino-Mongolian species seems to be almost as long as the shell is wide, while the hinge-line of the Japanese specimen is nearly half the maximum breadth of the shell.

O. ruber is a species established upon very poor material. On describing the Mongolian specimens GRABAU referred them to *O. ruber* "chiefly on the strength of the general form and relative convexity of valves." He adds, "Possibly if better material were available, our shells might prove to be distinct" (p. 252). Therefore, it may be plausible that I regard the Japanese species, though represented by only a single specimen, distinct from *O. ruber*, the most closely allied species, on the basis of the differences mentioned above.

Orthotetina eusarkos ABICH subsp. **lata** nov.

Pl. XIII.

Cf.

1900. *Orthotetina eusarkos*, SCHELLWIEN:—Neues Jahrb. f. Mineralogie, Geologie u. Palaeontologie, I, p. 8, pl. I, Fig. 1.

1900. *Orthotetes eusarkos*, FRECH & ARTHABER:—Beiträge zur Paläontologie und Geologie Oesterreich-Ungarns u. des Orients, Bd. XII, p. 248, Pl. XIX, Fig. 6.

1911. *Orthotetes eusarkos*, FRECH:—RICHTHOFEN's China, V, p. 123, Pl. XXVI, Fig. 1.

This is represented by a single specimen which is almost completely preserved. It seems to have almost all the features characteristic of the species *O. eusarkos*, the difference from the latter consisting in a few points that may be of some importance.

The outline of the shell is much more transverse than the Persian and Chinese specimens as illustrated by the authors quoted above. It is nearly semicircular. Valves are not so convex as in *O. eusarkos*. Ventral area is much lower and the ventral beak is less prolonged; a tendency

[1] FRECH:—RICHTHOFEN's China, Vol. V, p. 174, pl. XXVI, Fig. 4, 1911.
GRABAU:—The Permian of Mongolia, p. 251, pl. XXIV, Figs. 6 and 9, 1931.

toward twisting is observed. The specimen is markedly larger than the hitherto known specimens of *O. eusarkos*, as far as the references made by me are concerned; it measures about 65 mm., 88 mm. and 40 mm. in length, width and visceral thickness, respectively. Hinge-line is 65 mm. long, and about 15 mm. high; the cardinal angle is rounded.

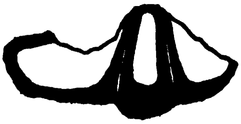


Fig. 6.
Cut-edge of the ventral beak of *Orthotetina eusarkos lata* showing the development of the dental plates. ca. ×3⅛.

A pair of slightly convergent dental plates is observed on the cut edge of the ventral beak (Fig. 6).

OBSERVATIONS: Quite recently GRABAU mentioned the occurence in the Permian Formation of Mongolia of *Orthotetina* cf. *eusarkos*.1) His specimen is by no means a good one. I rather doubt the affinity between the Mongolian specimen and *O. eusarkos*. The former need not be taken into consideration in connection with the Japanese specimen here described.

PRODUCTIDAE GRAY

DAVIESIELLA WAAGEN

(?) **Daviesiella comoides** (Sow.) subsp.

Pl. VIII, Fig. 2.

1932. (?) *Daviesiella comoides* subsp., HAYASAKA:—An Upper Carb. Brachiopod Fauna of Japan (Japanese), p. 548.

This is represented by only one incomplete specimen of a ventral valve of a big Productoid brachiopod. It is transversely oval in outline, the hinge-line representing the maximum breadth which is estimated to be about 170 mm., while the length is about 95 mm.

It is a very perplexing question to which of the following three genera, or subgenera, the present form does belong: *Daviesiella*, *Kansuella*1)

---

1) CHAO, Y. T.:—PRODUCTIDAE of China, Pt. II, p. 67, 1928. HELEN M. MUIR-WOOD:—The Classification of the British Carboniferous Brachiopod Subfamily PRODUCTINAE, p. 106, 1930.

or *Gigantella*,1) because the distinction of these three is not very easy, and the material at hand is only a single incomplete specimen of which necessary details are not accessible.

The distinction between *Kansuella* and *Daviesiella* is based on the difference in the internal structures, while in appearance they are very much alike.2) *Kansuella* is characterized by the transverse outline, large size, thick shell (the ventral being much thicker than the opposite), numerous fine, flexuous striae, concentric wrinkles, occasional radiating folds or wrinkles, and finally by low cardinal areas on both valves; the internal structures are just like "*Productus*" *giganteus*. *Kansuella*, again, "is derived from a papilionaceous type of *Chonetes* by suppression of the cardinal teeth............".3) Of the two groups of *Kansuella*, recognized by CHAO,4) the one which is represented by "*Productus*" *giganteus* is more likely to be compared with the present Japanese species. In other words, the Japanese fossil under consideration, though internally unknown, does not represent the typical characteristics of the genus *Kansuella*. The ventral valve is rather strongly convex.

"*Productus*" *giganteus* represents the genus, or subgenus, *Gigantella*, as mentioned above. MUIR-WOOD and PAECKELMANN think it as a good foundation. As to the distinction between *Daviesiella* and *Gigantella* (or "*Prod*" *giganteus*), PAECKELMANN dwells upon considering this5) and the diagonsis as *Gigantella* is given by him elsewhere.6)

Taking all this into consideration and taking up the specimen for examination, I am inclined to regard it as a form of *Daviesiella*, notwithstanding the very unfavourable state of preservation of the fossil. In the specimen we do not find either the concentric or radial wrinkles that are very commonly developed in *Gigantella*, *i. e.*, the *gigantea* group

---

1) SARYTCHEFF, T. G.:—The PRODUCTINAE of the Group *Prod. giganteus*, MART., from the Visean of Moscow, 1928. This work has not been accessible to me, but through the works of PAECKELMANN and MUIR-WOOD the generic features have been well understood. (MUIR-WOOD:—*op. cit.*: PAECKELMANN:—Die Fauna des deutschan Unterkarbons, 2 Teil, p. 231, 1931.)

2) CHAO:—PRODUCTIDAE of China, pt. I., p. 110 (*Striatifera kansuensiz* which is the type species of KANSUELLA), 1927.

3) CHAO:—*op. cit.*, 1928.

4) CHAO:—*op. cit.*, p. 68, 1928.

5) PAECKELMANN:—*op. cit.*, p. 232-233, 1931.

6) PAECKELMANN:—*op. cit.*, p. 237, 1931.

of *Producti.* On the surface of the shell fine, thread-like radial striae are developed that are uniform in thickness all over the surface, and increase in number anteriorly.

Thus the fossil is here provisionally described as a *Daviesiella,* in which the species *comoides,* among the many, appears to be most closely allied.

Compared with *Daviesiella comoides* in a wider sense, the only perceptible differences are the larger size of the shell, the more convex ventral valve, the lower (?) cardinal area and the less numerous radial striae of the shell surface.

In the specimen under consideration, the striae or lirae range from 6 to 8 in 5 mm. at a distance of about 20 to 25 mm. from the beak, while they are from 9 to 12, or even up to 14–15 in *D. comoides.*[1]

The difference of the number of the surface striae must not be overlooked in the systematic of this group of fossils. Very recently PAECKELMANN, in describing the German Carboniferous brachiopods, created a new variety *rhenana* of *D. comoides,* on account of the much larger number of surface striae and of the lower cardinal area.[2] In it they number 17–21 in 5 mm. in the beak region. PAECKELMANN described a number of different species and varieties beside *D. comoides rhenana* but in none of these the surface striation is so sparse as in the Japanese form under consideration.

In point of the size of the shell, the Japanese fossil exceeds most of the known specimens of *D. comoides* hitherto recorded. *D. comoides* var. *Destinezi* (VAUGHAN)[3] is reported by DELÉPINE to be represented by some very large specimens in the Visean of Belgium.[4] The original or the type specimen in the Geological Museum of the University of Liège is 168 mm. and 96 mm. in width and length. Another specimen in the same collection measures 180 mm. in breadth. The largest specimen of the same species, which is in the Museum of Bruxelles, and was described by DELÉPINE,[5] attains a length of 220 mm. and a width of 105 mm.

---

1) DAVIDSON:—Monogr. Carb. Brach., p. 180, 276, 1858–63. PAECKELMANN:—*op. cit.*, p. 284, 1930.

2) PAECKELMANN:—*Ditto*, pp. 284-289, Pl. 19, Figs. 1-2, 1930.

3) VAUGHAN, A.:—Correlation of Dinantian and Avonian. p. 46, 1915.

4) DELÉPINE, G.:—Les Brachiopodes du Marbre Noir de Dinant. (Viséen inférieur), p. 17, 1928.

5) *Loc. cit.*

Thus the Japanese specimen may be regarded as differing from the species *D. comoides*. VAUGHAN's subspecies *Destinezi* is characterized further by the strong convexity of the ventral valve, as well as by the very fine striae.1) This last point is an evidence for distinguishing the Belgian form from the Japanese one, if the more transverse outline of the former were not to be taken into consideration.

PRODUCTUS SOWERBY

Productus (Echinoconchus) defensus (THOMAS)

Pl. XII, Figs. 2 and 3.

1924. *Prod. punctatus*, HAYASAKA :—On the Fauna of the Anthrac. Limest. Ômi-mura, etc., p. 31, Pl. V, Fig. 8.

1931. *Prod.* (*Echinoconchus*) *defensus*, PAECKELMANN :—Die Fauna des deutschen Unterkarbons, 2, Teil : Die Brachiopoden, 2, Teil. p. 157, Pl. XVI, Figs. 1-3, With synonymy.

1932. *Prod.* (*Echinoconchus*) *punctatus*, H. DE TERRA :—Geol. Forschungen im westl. K'unlun u. Karokorum-Himalaya, p. 164, Pl. XIII, Fig. 3.

1932. *Prod.* (*Echinoconchus*) *defensus*, HAYASAKA :—An Upper Carb. Brachiopod Fauna of Japan (Japanese), p. 548.

The Japanese specimens here being considered belong to the longitudinally oval group of *Echinoconchus* with narrower concentric bands, which, in other respects, are not distinguishable from *P.* (*Echinoconchus*) *punctatus*, a very widely distributed species. "Als äussere Hilfsmittel zur Unterscheidung" between these two species "kann im allgemeinen der verschiedene Umriss (breitoval bei *Pr. punctatus*, länglich-oval bis gerundet quadratisch bei *Pr. defensus*), die flache Wölbung der Wirbelpartie bei *Pr. punctatus* und die engere Faltung der Schale bei *Pr. defensus* dienen."

HORIZON : S-D in English-Scottish Stratigraphy, *i. e.*, the Upper Visean.

SPIRIFERIDAE KING

A NOTE ON THE SPIRIFER OF THE NABEYAMA FAUNULE

Of the genus *Spirifer*, I had on the former occasion only a single broken specimen, which is characterised by the small number of radial

---

1) *Loc. cit.*

ribs or plications that are quite wide. I therefore called it provisionally *Spirifer* aff. *rockymontanus* MARCOU.[1] In my subsequent collections there are a few more specimens of *Spirifer*. Though they are all fragmentary specimens and consequently it is not easy to decide what species they really are, there are a few characters they have in common. The radial plications, for instance, are more or less strongly angular and they are very few in number, 5 or 6 on each wing. Thus the North American species referred to the other time does not seem to resemble them because the ribs are not so angular nor are they so few in number. On the other hand, the newly collected specimens and the old one are quite alike in many respects, the only perceptible differences being that the radial ribs are seven on a wing in the latter and that it is a little more transverse in outline than the new material. The old specimen, however seems to have yielded, if slightly, to an antero-posteriorly directed compression, and is consequently a little deformed and the plications look much less angular.

On examining these specimens of the old and new collections together—it is ascertained that they occurred at the same spot—there is hardly any reason to separate them into different species. They, as a whole, seem to stand very close to the group of Spirifers which is represented by *Sp. grandicostatus* M'COY, as will be described below.

SPIRIFER SOWERBY

Spirifer acutiplicatus, n. sp.

Pl. XIV, Figs. 1-4: Pl. VIII, Fig. 8.

1926. *Spirifer* aff. *rockymontanus*, HAYASAKA:—Proc. Imp. Acad. II, No. 10, p. 552.
1932. *Spirifer* sp. n., HAYASAKA:—An Upper Carb. Brachiopod Fauna of Japan (Japanese), p. 548.

The shell is transversely subrhomboidal, the width being a little less than twice the length. Hinge-line is straight, and almost corresponds to the maximum width of the shell. Cardinal angle is obtuse or rounded.

---

1) GIRTY:—The Carboniferous Formations and Faunas of Colorado, p. 383, Pl. VI, Figs. 4-7, 1903.

Valves are nearly equally convex; the ventral beak slightly overhangs the wide and low cardinal area; the dorsal area is low and linear. The ventral valve has a median depression which begins at a distance from the beak; it widens quite abruptly toward the front, where it extends upwards like a tongue. In this depression there are 3 to 4, or sometimes a few more, low plications that are recognised in the beak region. They become obsolete in the anterior half. In one specimen a median rib alone extends to the margin. On the wings or alar parts of the valve 5 to 7 rather wide and angular ribs or plications develop; the interspaces are equally wide and angular. In the dorsal valve, there is a very prominent median fold, which is not very distinct in the beak region, but becomes quite wide at the anterior margin, thus it looks from above like an acute isoceles triangle. The top of the fold is quite acute. In the posterior or umbonal half of the fold there are 3 or 4 narrower and lower ribs. The surface of the valves are, moreover, ornamented with concentric growth wrinkles that are more distinct toward the margin. The radial plications being angular, these growth wrinkles become somewhat lamellar, and thus give rise to the sculpture which is commonly found in *Spiriferina.*

In one of the specimens radial plications are not equal in strength, larger and smaller ones being in alteration (Fig. 4). In this specimen the plications show a tendency to multiply by interpolating smaller ones between the larger.

Measuring the representative specimen (Fig. 2, Pl. XIV.), the following dimensions are obtained: Length, 35 mm.; Width, 41 mm.; Depth, 26 mm.

OBSERVATIONS: As has been remarked, the present species is characterised by the angular form of the radial plications in the first place, and by the fact that these plications are very few, in the second place. Among the known species of *Spirifer* there are a few that have similar characteristics. They may be represented by the uncertain species, *Spirifer grandicostatus* M'COY1) as well as by *Spirifer decemplicatus*

---

1) M'COY:—Ann. of Natural History, 2nd ser. Vol. X, p. 422, 1853:—Brit. Palaeoz. Fossils, p. 417, pl. 30, Fig. 29, 1854. DAVIDSON:—Monogr. Brit. Carb. Brachiopoda, p. 33, Pl. V, Figs. 38, 39; Pl. VII, Figs. 7-16, 1857.

M'COY.¹⁾ As DAVIDSON remarked, *Sp. decemplicatus* is a very uncertain species. If DE KONINCK's identification of *Sp. decemplicatus* is reliable, the cardinal area of the ventral valve is far lower in my specimens than in it. About *Spirifer grandicostatus*, DAVIDSON, in the later part of his monograph,²⁾ wrote that this is but a varietal form of *Spirifer trigonalis* MARTIN. Several other forms, including *Spirifer bisulcatus*, were regarded by him as to belong to this species of MARTIN. As a matter of fact, some of these "varieties" look very much alike but others are quite different from one another. It appears that DAVIDSON extended the range of variation of *Spirifer trigonalis* a little too far.

The present species differs from *Spirifer grandicostatus*, which, I think, is one of the most allied species, in not having "five or six very much smaller obscure radiating ridges" on "the narrow flattened sides".³⁾ Perhaps the lamellar concentric wrinkles may also be considered as one of the specific characters of the present species.

MANSUY sometime ago mentioned the occurrence of *Spirifer* cf. *grandicostatus* in the Carboniferous of Tongking, Indochina.⁴⁾ The specimen cannot be said to be very well preserved, but the general morphological features impress us with its very close affinity to the British species. In certain points the Japanese species resembles the former.

SQUAMULARIA GEMMELLARO

Squamularia sp.

Pl. III, Figs. 2 and 3.

This genus is distinguished from Reticularia by lacking any septal structures inside. There are several specimens of this group of brachiopods in my collection. In a few of them the absence of the dental plates and the septum has been ascertained. Other specimens are in-

---

1) DAVIDSON :—Monogr. Brit. Carb. Brachiopoda, p. 43, pl, VIII, Figs. 2, 3, 1857. DE KONINCK :—Fanne du Calc. Carb. de la Belgique, pt. 6, p. 150, pl. XXVI, Figs. 21-23, 1887.

2) DAVIDSON :—*op. cit.*, p. 222, 1862.

3) M'COY :—Ann. Nat. Hist. 2nd ser. Vol. X, p. 422, 1853.

4) MANSUY :—Mém. du Service Géol. de l'Indochine, Vol. II, Fasc. V, p. 23, Pl. IV, Fig. 1, 1913.

complete and their inner features are not accessible. Some of them may possibly belong to the genus *Reticularia.*

Among the specimens at hand, at least two types are distinguished, one having finer concentric wrinkles, and the other with coarser ones. The latter group resembles, for instance, *S. waageni,*1) while the former is comparable with such a species as *S. guadalupensis.*2)

For a farther study more material is necessary.

MARTINIA M'COY

Martinia sp.

Pl. XIV, Figs. 5 and 6.

The genus *Martinia* is represented in my collection by several specimens that are not very well preserved. A few of the specimens are elongate (Fig. 6), while others are rather transverse (Fig. 5), thus suggesting the existing of more than one species. On the other hand, it is not easy to draw a line of demarkation between any two of them. Without a greater number of specimens it is not safe to try specific determination of such a group of brachiopods.

The specimens, however, have in common the following characters. (1) The ventral valve is larger and deeper than the dorsal one; (2) the ventral area is high and triangular, with a distinct triangular delthyrium in the middle; (3) the dorsal area is low and almost linear; (4) the ventral median sinus is flat and wide, and it becomes visible in front of the visceral part; (5) the dorsal fold, correspondingly, is not very sharp; (6) the surface sculpture is obsolete, except for rather faint concentric striae that are more or less distinct toward the margin; (7) there is no trace of septal structures.

The transverse specimen (Fig. 5) may be compared with *M. remota* CHAO from the Wangchiapa limestone of Kweichow,3) although there is a difference in the outline of the shells; the Japanese specimen is

---

1) CHAO:—Carbon. and Perm. Spiriferids of China, p. 93, pl. XI, Figs. 7-11, 1929.

2) GIRTY:—The Guadalupian Fauna, p. 367, Pl. XIV, Figs. 1-6, 1908.

3) CHAO:—Carbon. and Perm. Spiriferids of China, p. 78, pl. X, Fig. 8, 1929.

somewhat pentagonal, while the Chinese one is transversely oval. In having a pentagonal outline, *M. triquetra* GEMM. var. *pentagona* GROEBER[1] may be more closely allied to the Japanese form, although their identity should not be insisted upon.

The elongate specimen (Fig. 6) has an outline of a lozenge, the length and width being almost equal. Perhaps *M. rhomboidalis* GIRTY[2] of the Guadalupian Fauna may be one of the comparable species.

(Oct. 25, 1932)

---

1) GROEBER:—Ueber die Faunen des untercarb. Transgressionsmeeres des zentralen Tian-Schan, etc., p. 240, Pl. XXIX, Fig. 3, 1908. (Middle Carboniferous).

2) GIRTY:—The Guadalupian Fauna, p. 364, pl. XIII, Figs. 11-14, 1908. (Lower Permian).

BIBLIOGRAPHY

In this bibliography, only the works referred to in the text are arranged in an alphabetical order according to authors. Many other works have been consulted but they are not enumerated here.

1. Chao, Y. T.:—Productidae of China, Part I: *Producti.* Palaeontologia Sinica, Series B, Vol. V, Fasc. 2, 1927.
2. Chao, Y. T.:—Productidae of China, Part II:—Chonetinae, Productinae and Richthofeninae. Palaeontologia Sinica, Series B, Vol. V, Fasc. 3, 1928.
3. Chao, Y. T.:—Carboniserous and Permian Spiriferids of China. Palaeontologia Sinica, Series B, Vol. XI, Fasc. 1, June 1929.
4. Davidson, Th.:—Monograph of the British Carboniferous Brachiopoda, 1871.
5. Delépine, G.:—Les Brachiopodes du Marbre Noir de Dinant (Viséen inférieur). Mémoires du Musée Royal d'Histoire Naturelle de Belgique, No. 37, 1928.
6. Eastman, Charles R.:—Text-Book of Palaeontology, Vol. I, 1913.
7. Fliegel, G.:—Ueber obercarbonische Faunen von Ost- und Südasien. Palaeontographica, XLVIII, 1901.
8. Frech, F. und Arthaber, G.:—Ueber das Paläozoicum in Hocharmenien und Persien. Beiträge zur Paläontologie und Geologie Oesterreich-Ungarns und des Orients, Bd. XII, Heft IV, Feb. 1900.
9. Frech, F.:—China; Ergebnisse eigener Reisen und darauf gegründeter Studien von Ferdinand Freiherrn v. Richthofen, Bd. V. 1911.
10. Girty, G. H.:—The Carboniferous Formations and Faunas of Colorado. U. S. Geological Survey, Professional Paper 16, 1903.
11. Girty, G. H.:—The Guadalupian Fauna. U. S. Geological Survey, Professional Paper, 58, 1908.
12. Grabau A.:—The Permian of Mongolia. Natural History of Central Asia, Vol. IV. 1931.
13. Gröber, P:—Ueber die Faunen des untercarbonischen Transgressionsmeeres des zentralen Tian-Schan, die in der Umgebung des Sart-dschol-Passes gefunden worden sind. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band XXVI, pp. 213-248, 1908.
14. Hayasaka, I.:—On the Fauna of the Anthracolithic Limestone of Ômi-Mura in the Western Part of Echigo. The Science Reports of the Tôhoku Imperial University, Second Series (Geology), Vol. VIII, No. 1, 1924.
15. Hayasaka, I.:—On Some Paleozoic Molluscs of Japan, 1. Lamellibranchiata and Scaphopoda. The Science Reports of the Tôhoku Imperial University, Second Series (Geology), Vol. VIII, No. 2, August 1925.
16. Hayasaka, I.:—On the New Carboniferous Brachiopod Fauna from the Ashio Mountains, Japan. Proceedings of the Imperial Academy, 2, No. 10, pp. 551-553, 1926.
17. Hayasaka, I.:—An Upper Carboniferous Brachiopod Fauna of Japan (in Japanese) Tisitugaku Zassi (The Journal of the Geological Society of Tôkyô), Vol. XXXIX, No. 468, Sept. 1932.
18. King, Philip Burke:—The Geology of the Glass Mountains, Texas: Part I. Descriptive Geology, Oct. 1930.
19. King, Robert Evans:—The Geology of the Glass Mountains, Texas: Part II. Faunal Summary and Correlation of the Permian Formations with Description of Brachiopoda. Nov. 1930.
20. Koninck, L. G. de:—Faune du Calcaire Carbonifére de la Belgique, 6 partie, Brachiopodes. Annales du Musée Royal d'Histoire Naturelle de Belgique, Tome XIV, 1887.

21. McCoy, F.:—Contributions to British Palaeontology: On Some New Brachiopoda from the Carboniferous Limestone. Annals of Natural History, Series 2, Vol. X, 1852.

22. Mansuy, H.:—Nouvelle Contribution a la Paléontologie de l'Indochine, 1-Contribution a l'Étude des Faunes Paléozoiques et Triasiques du Tonkin. Mémoires du Service Géologique de l'Indochine, Vol. XI, Fasc. V, pp. 1-29, 1913.

23. Muir-Wood, Helen M.:—The Classification of the British Carboniferous Brachiopod Subfamily Productinae Annals and Magazine of Natural History, Series 10, Vol. V, pp. 100-108, 1930.

24. Newell, Norman D.:—New Schizophoriidae and a Trilobite from the Kansas Pennsylvanian. Journal of Paleontology, Vol. V, No. 3, pp. 260-269, Sept. 1931.

25. Ozawa, Y.:—Paleontological and Stratigraphical Studies on the Permo-Carboniferous Limestone of Nagato, Part II. Paleontology. Journal of the College of Science, Imperial University of Tôkyô, Vol. XLV, Art. 6, June 1925.

26. Paeckelmann, Werner:—Die Fauna des deutschen Unterkarbons, 1 Teil, 3: Die Brachiopoden, 1 Teil. Abhandlungen der Preussischen Geologischen Landesanstalt, Neue Folge, Heft 122, pp. 143-326, 1930.

27. Paeckelmann, Werner:—Die Fauna des deutschen Unterkarbons, 2 Teil: Die Brachiopoden, 2 Teil. Abhandlungen der Preussischen Geologischen Landesanstalt, Neue Folge, Heft 136, 1931.

28. Sagawa, Y.:—*Helicoprion*, a Carboniferous Fish found in Japan and Russia (in Japanese). Tigaku Zassi (The Journal of Geography), Vol. XII, No. 133, pp. 26-29, 1900.

29. Sarytscheff, T. G.:—The Productidae of the group *Prod. giganteus* Martin, from the Visean of Moscow. Arbeiten des geologischen Wissenschaftlichen Untersuchungsinstituts bei der Physikalisch-Mathematischen Fakultät der Ersten Moskauer Staatsuniversität, 1928. This work has not been accessible.

30. Schellwien, E.:—Beiträge zur Systematik der Strophomeniden des oberen Palaeozoicum. Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, Bd. 1., pp. 1-15, 1900.

31. Schuchert, Charles and Cooper, G. Arthur:—Synopsis of the Brachiopod Genera of the Suborders Orthoidea and Pentameroidea, with Notes on the Telotremata. American Journal of Science, Vol. XXII. pp 241-251, Sept. 1931.

32. Thomas, Ivor:—The British Carboniferous Orthotetinae. Memoirs of the Geological Survey of Great Britain: Palaeontology. Vol. I, part 2, 1910. This has not been accessible during the course of this study.

33. Trautschold, H.:—Die Kalkbrüche von Mjatschkowa, 1878.

34. Trinkler, E. und Terra, H. de:—Wissenschaftliche Ergebnisse der Dr. Trinklerschen Zentralasien-Expedition, Bd. II.—Geologische Forschungen im westlichen K'unlun und Karakorum-Himalaja, 1932.

35. Tschernyschew, Th.:—Die obercarbonischen Brachiopoden des Ural und des Timan. Mémoires de Comité Géologique, Vol. XVI, No. 2, 1902.

36. Vaughan, A.:—Correlation of Dinantian and Avonian. Quarterly Journal of the Geological Society of London, Vol. LXXI, pp. 1-52, Sept. 1915.

37. Waagen, W.:—Productus-Limestone Fossils, Brachiopoda. Palaeontologia Indica, Ser, XIII., Vol. 1, 1883.

38. Yabe, H.:—On a Fusulina-Limestone with *Helicoprion* in Japan. Tisitugaku Zassi (The Journal of the Geological Society of Tôkyô), Vol. X, No. 113, pp. 1-13, 1903.

39. Yakowlew, N.:—Die Fauna der oberen Abteilung der Paläozoischen Ablagerungen im Donez-Bassin. Mémoires de Comité Géologique, Nouv. Sér. Livraison 79, 1912.

PLATE III.

Explanation of Plate III.

(All the figures are in natural size)

Fig. 1. *Orthotichia japonica* HAYASAKA. (See Pls. IV, V, and Fig. 1, Pl. VI.)
Specimen No. 3 (**Holotype**): *a*, dorsal view; *b*, ventral view.

Fig. 2. *Squamularia* sp., a dorsal valve.

Fig. 3. *Squamularia* sp., another specimen: *a*, ventral view; *b*, lateral view.

3*b*

1*a*

3*a*

2

1*b*

PLATE IV.

Explanation of Plate IV.

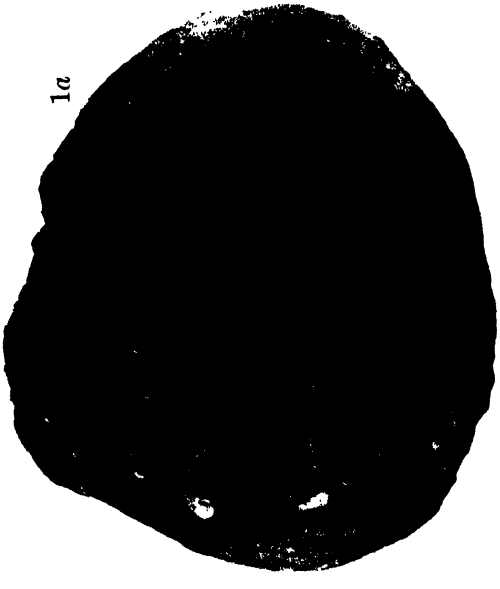
(All the figures are in natural size)

Orthotichia japonica HAYASAKA.

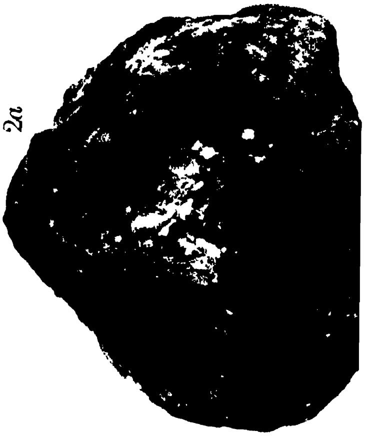
(See Fig. 1, Pl. III, Pl. V, & Fig. 1, Pl. VI.)

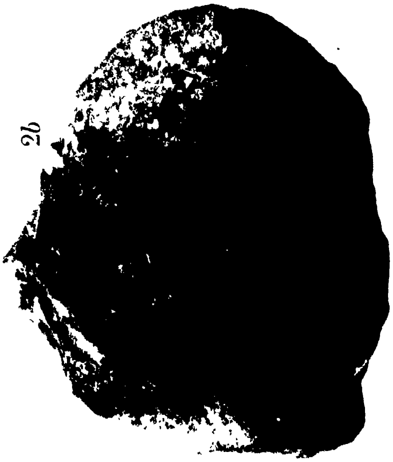
Fig. 1. Specimen No. 4. A slightly deformed specimen: *a*, dorsal view; *b*, ventral view. The ventral beak being broken off, the septal structure inside is observed in 1, *b*.

Fig. 2. Specimen No. 10. The smallest specimen of the species at my disposal: *a*, dorsal view; *b*, ventral view; *c*, posterior view.


1a

1b


2a


2b

2c

PLATE V.

Explanation of Plate V.

(Figures are in natural size)

Orthotichia japonica HAYASAKA.

(See Fig. 1, Pl. III, Pl. IV, Fig. 1, Pl. VI.)

Specimen No. 7 (One of the best paratypes): *a*, dorsal view; *b*, ventral view; *c*, lateral view; *d*, anterior view.

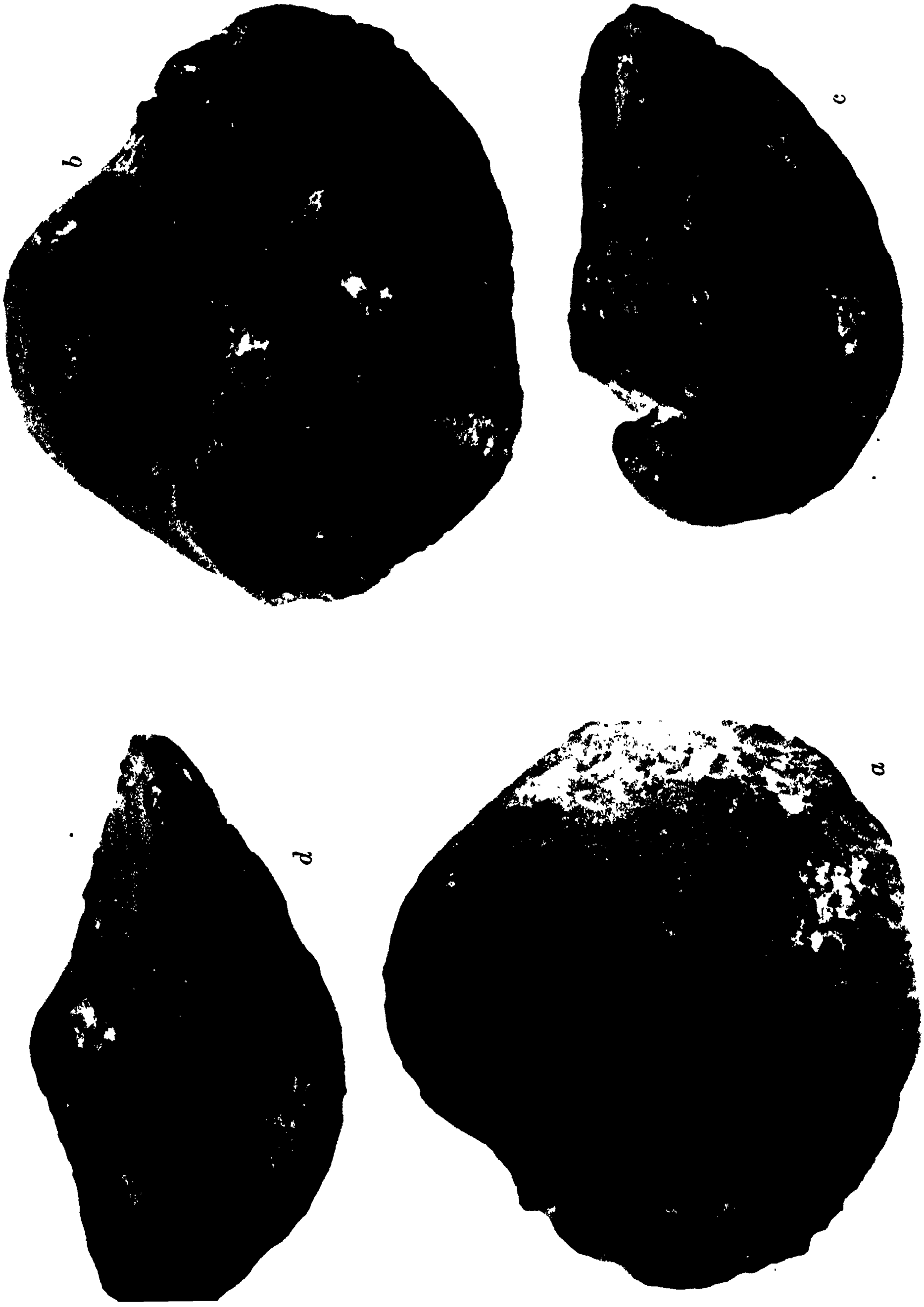

b
c
d
a

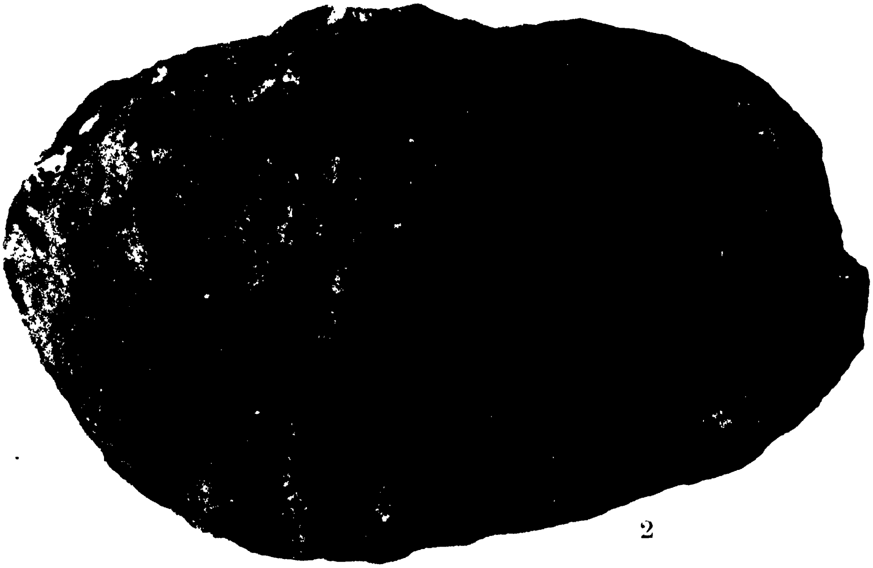
PLATE VI.

Explanation of Plate VI.

(All the figures are in natural size)

Fig. 1. *Orthotichia japonica* HAYASAKA. (See Fig. 1, Pl. III; Pl. IV; Pl. V.) Specimen No. 2; an obliquely compressed specimen; dorsal view.

Fig. 2. *Meekella gigantea* HAYASAKA. (See Pl. X; Pl. XI; Fig. 3, Pl. IX.) Specimen No. 3: ventral view. The beak was cut and polished to show the septal structure.



2

1

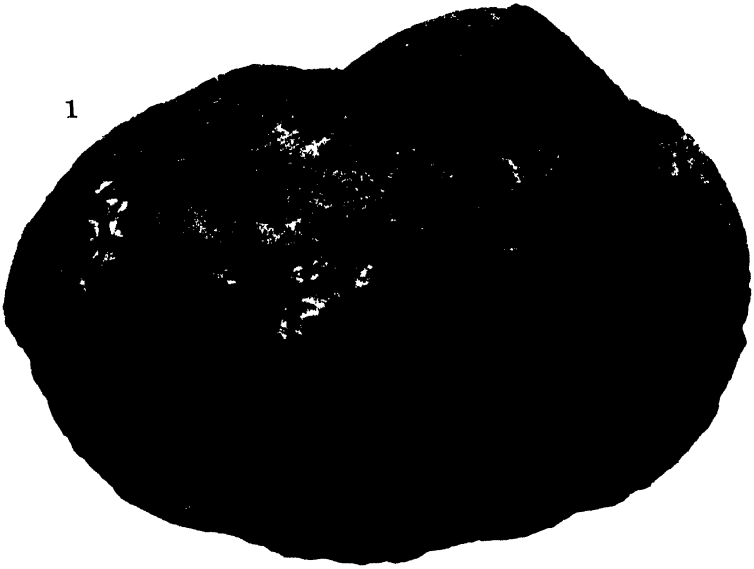


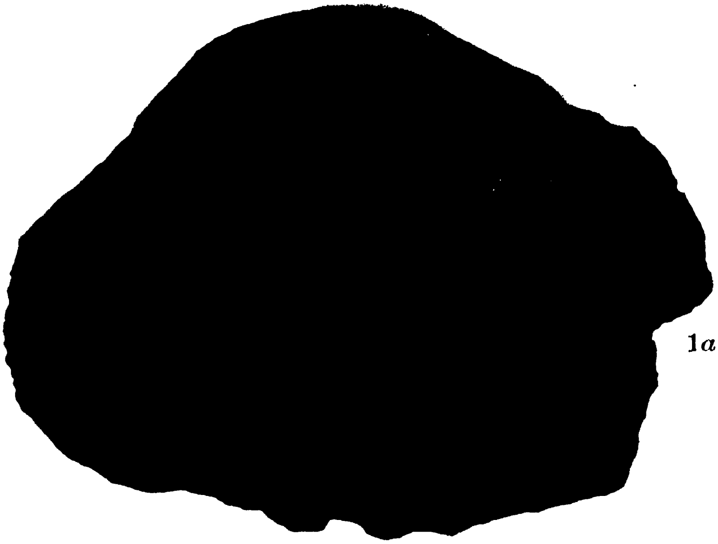
PLATE VII.

Explanation of Plate VII.

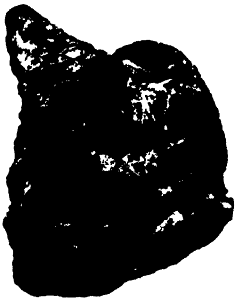
(All the figures are in natural size)

Fig. 1. *Orthotichia japonica* HAYASAKA subsp. *striata* HAYASAKA. Specimen No. 1 (**type**): *a*, dorsal view; *b*, ventral view. Note the rather coarse, thread-like striae or lirae on the shell surface.

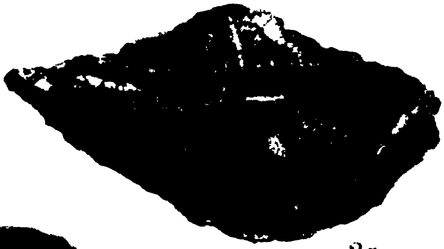
Fig. 2. *Orthotetina planoconvexa* HAYASAKA (**Holotype**). *a*, posterior view, with ventral valve, to show the high ventral area with the delthyrium in the center; *b*, lateral view, showing the more or less zigzag pattern of the antero-lateral shell commissure,



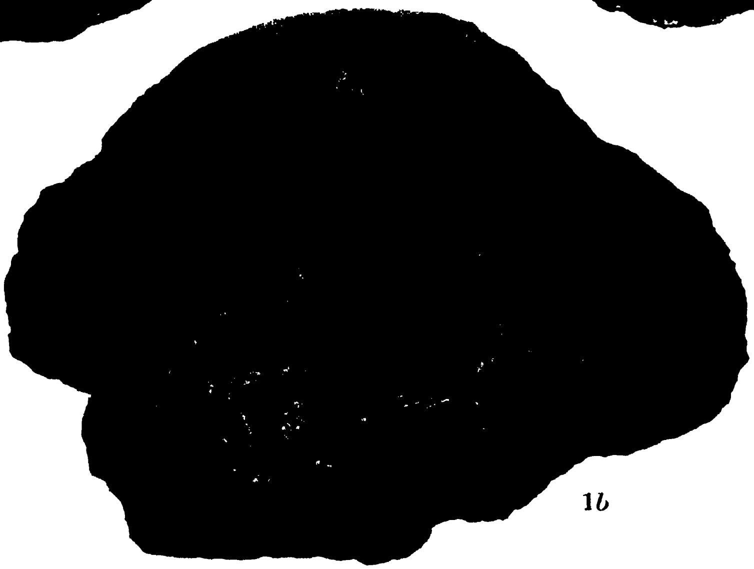
1*a*



2*b*



2*a*



1*b*

PLATE VIII.

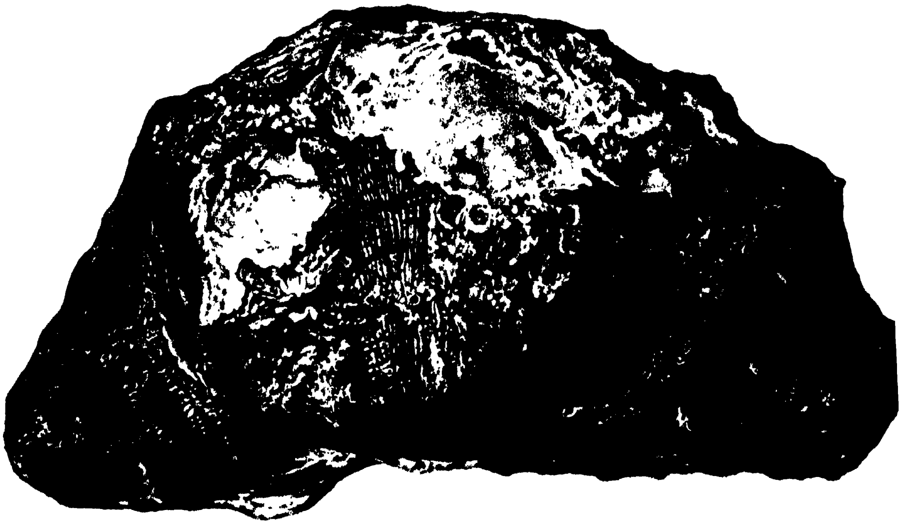
Explanation of Plate VIII.

(All the figures are the photographic reductions to natural size from elaborate sketches made by Mr. SAKUMA)

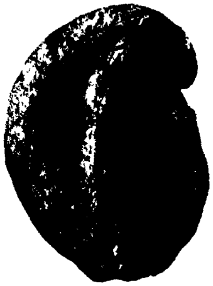
Fig. 1. *Enteletes acutiplicatus* HAYASAKA. (**Holotype**). *a,* antero-posterior view showing the characteristic septal structure; *b,* anterior view, with the ver acute zigzag course of the anterior margin; *c,* lateral view.

Fig. 2. (?) *Daviesiella comoides* subsp; a ventral valve, posterior view, showin the low linear cardinal area.

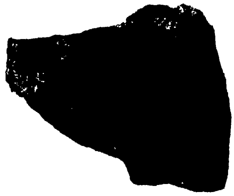
Fig. 3. *Spirifer acutiplicatus* HAYASAKA. (See Figs. 1-4, Pl. XIV.) Specime No. 2. An antero-posteriorly compressed specimen.



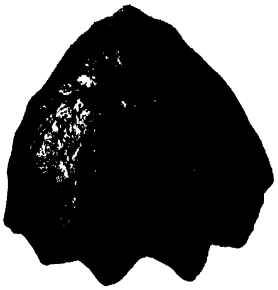
2



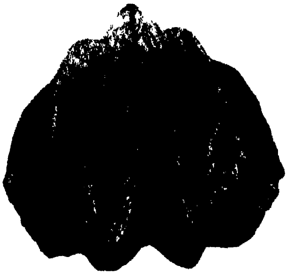
1c



3



1*a*



1*b*

PLATE IX.

Explanation of Plate IX.

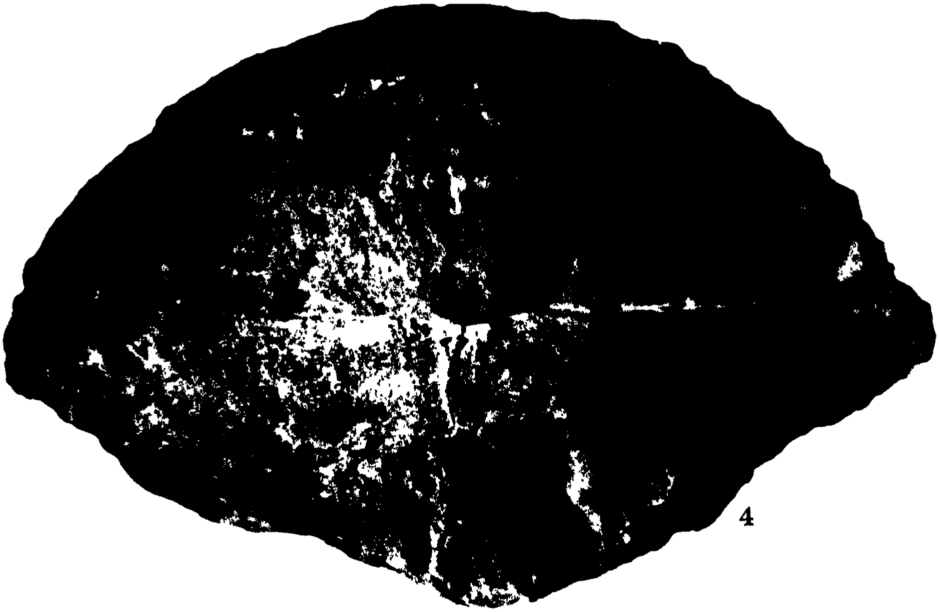
(All the figures except Fig. 4 are in natural size)

Fig. 1. *Streptorhynchus* sp. An incomplete specimen, with its ventral beak broken off. *a*, dorsal view; *b*, anterior view, showing a slightly asymmetrical undulation of the commissure.

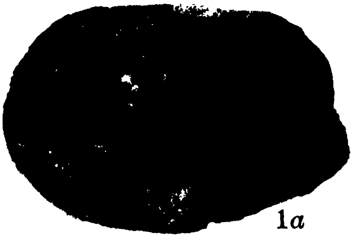
Fig. 2. *Streptorhynchus* sp. Another specimen, of which the ventral beak portion has been cut off and polished to examine the inner structure. In the figure the ventral valve is above, and the dorsal below. The black hemispherical portion in the upper part of the figure is the oblique cut-edge of the ventral beak.

Fig. 3. *Meekella gigantea* HAYASAKA. (?) (See Fig. 4;Fig. 2, Pl. VI; Pl. X; Pl. XI; Fig. 1, Pl. XII.) A small specimen which resembles the gigantic *Meekella* in its external aspects. The inner structures cannot be examined.

Fig. 4. *Meekella gigantea* HAYASAKA. Posterior view of the Holotype (Pl. X), slightly reduced.



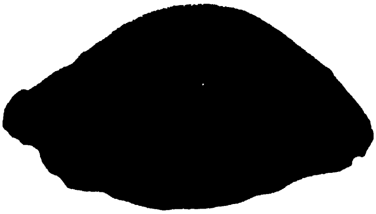
4



1*a*

2

1*b*



3

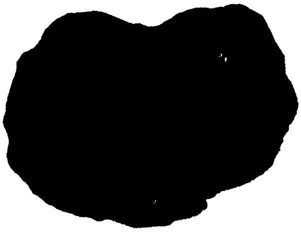
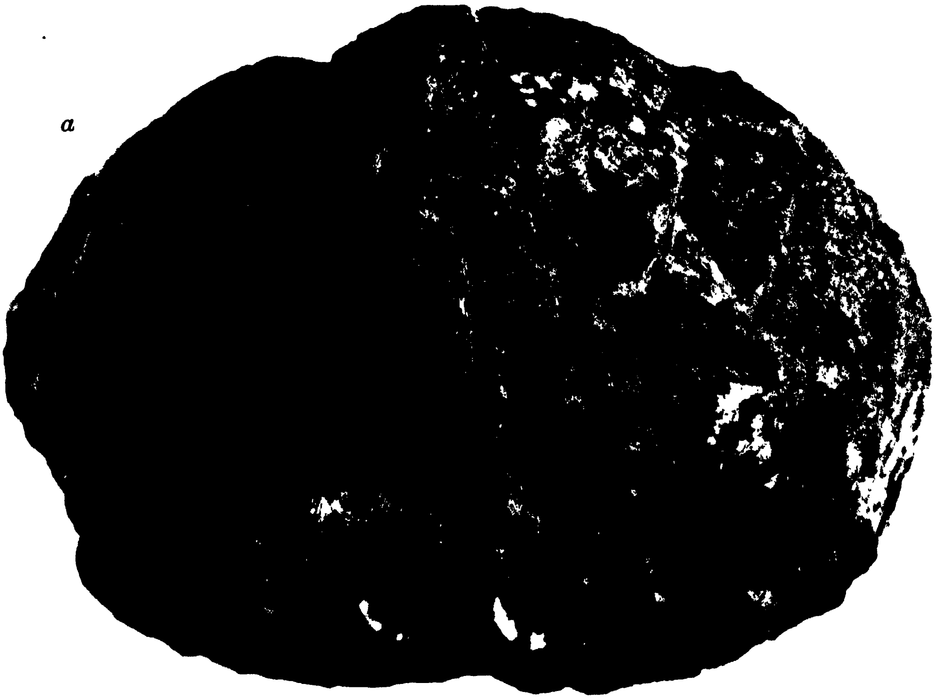


PLATE X.

Explanation of Plate X.

(Figures are in natural size)

Meekella gigantea HAYASAKA. (See Fig. 2, Pl. VI; Pl. XI; Fig. 4, Pl. IX;Fig. 1, Pl. XII) Specimen No. 1 (**Holotype**). This is the largest of the specimens at hand. *a*, dorsal view; *b*, ventral view. The characteristic plications and striae or lirae are very distinctly represented. In this specimen the septal structure in the ventral valve is recognized on the weathered surface, though it is not very distinct in the figure *b*.


a

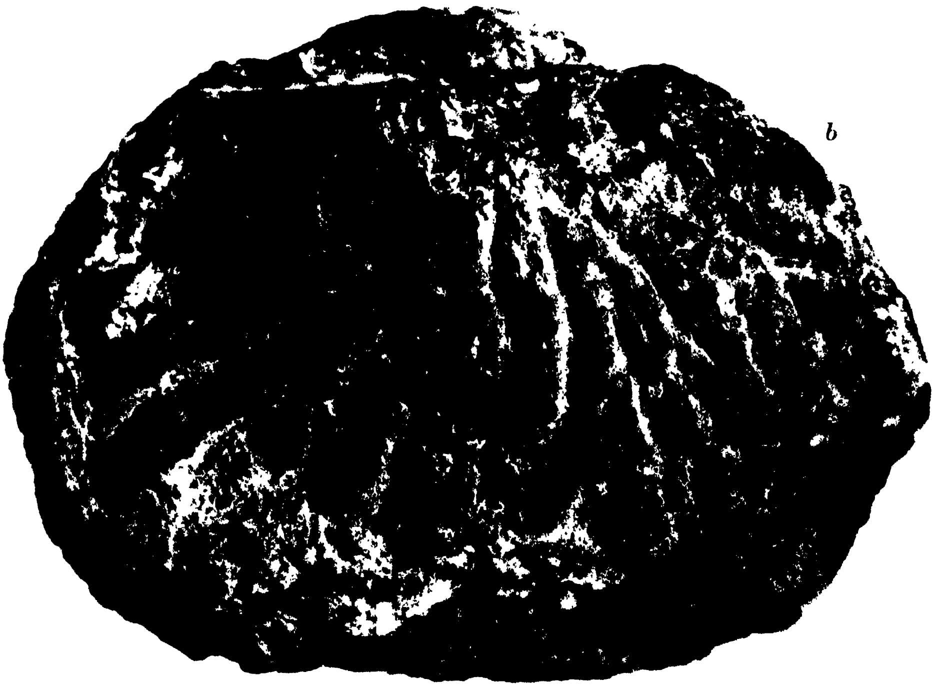
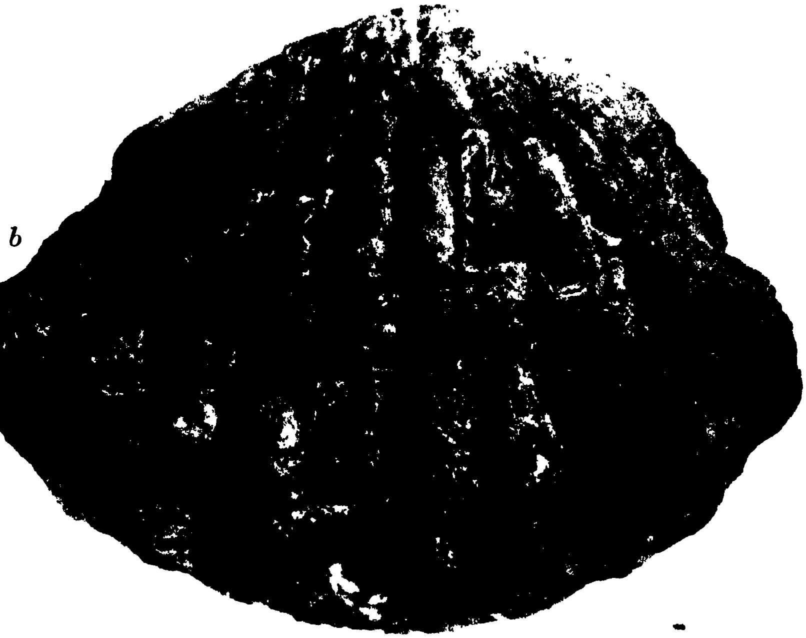

b

PLATE XI.

Explanation of Plate XI.

(Figures are in natural size)

Meekella gigantea HAYASAKA. (See Fig. 2, Pl. VI; Figs. 3, 4, Pl. IX; Pl. XII.) Specimen No. 2. *a*, dorsal view; *b*, ventral view. The posterior view of this specimen has been sketched by SAKUMA, and its photographic reproduction is given in the text of this paper (Text-fig. 4, p. 27.) and Fig. 1 *a*, Plate XII.


b

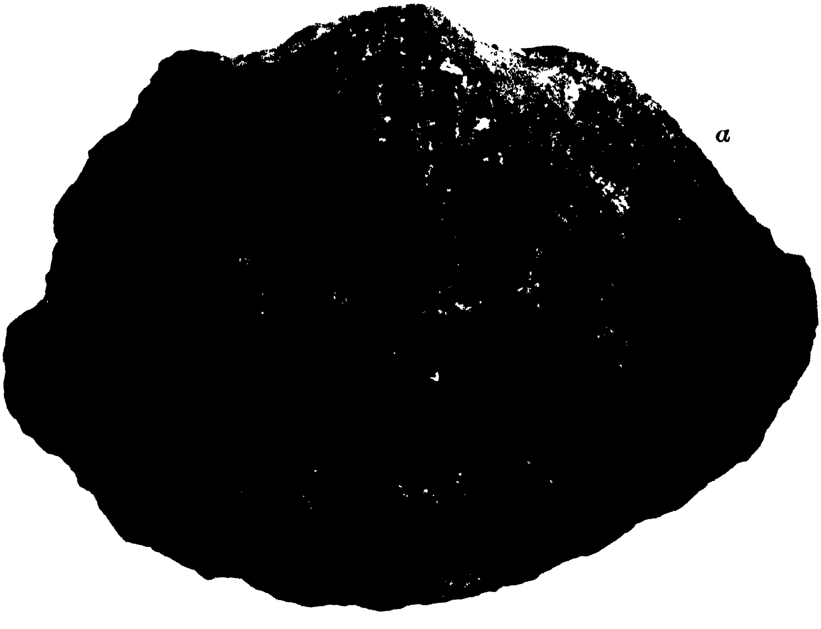

a

PLATE XII.

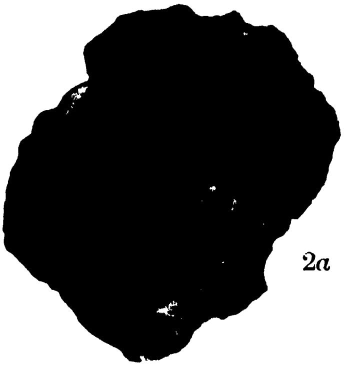
Explanation of Plate XII.

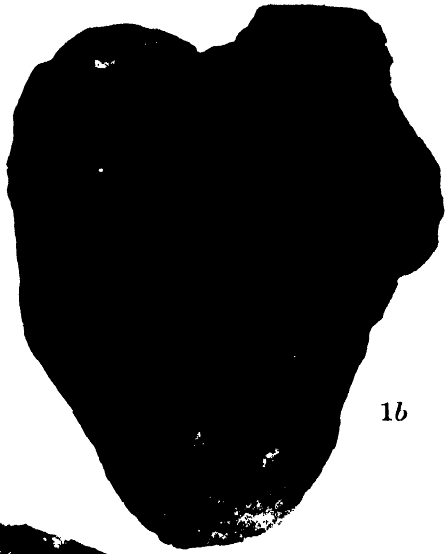
(All the figures are in natural size)

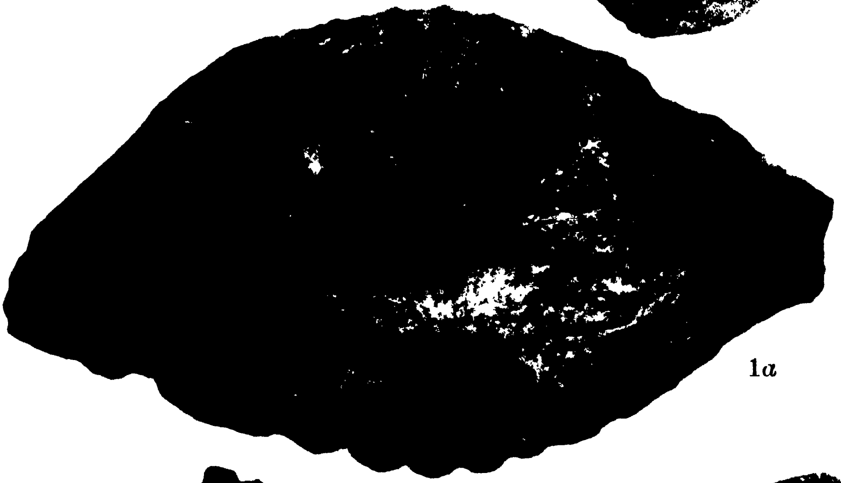
Fig. 1. *Meekella gigantea* HAYASAKA. (See Fig. 2, Pl. VI; Figs. 3, 4, Pl. IX; Pl. X; Pl. XI.) Specimen No. 2 (Paratype) (See the figures on Plate XI). *a*, posterior view; *b*, lateral view. These figures are given to show the large triangular and high cardinal area. The beak has been cut off and the cut-edge has been polished so that the peculiar dental plates can be observed. The mode of the development of the dental plates is shown in the (Text-fig. 4, p. 27.) of this paper.

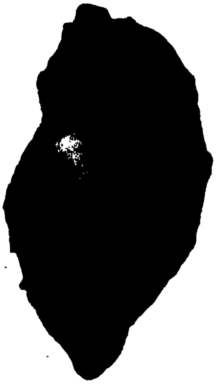
Fig. 2. *Productus* (*Echinoconchus*) *defensus* (THOMAS). A ventral valve. *a*, ventral view; *b*, lateral view.

Fig. 3. *Productus* (*Echinoconchus*) *defensus* (THOMAS). Another specimen; ventral valve.


2*a*


1*b*


1*a*


2*b*

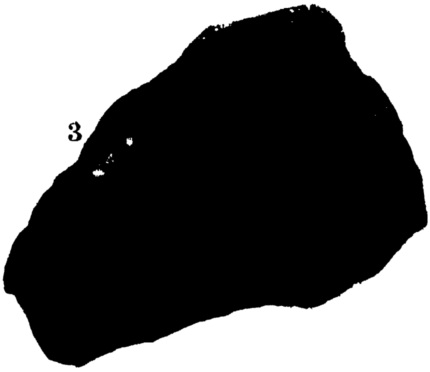

3

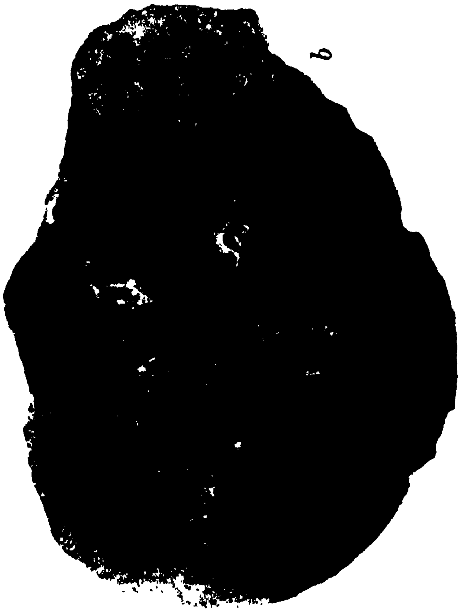
PLATE XIII.

Explanation of Plate XIII.

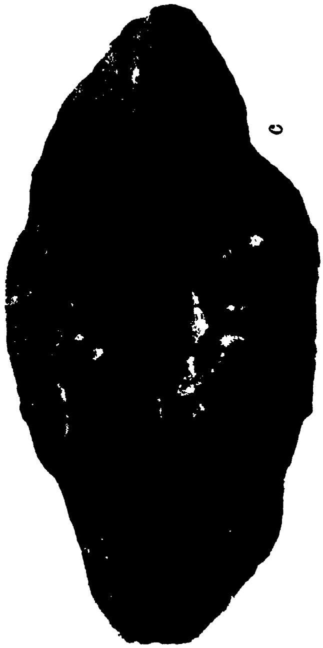
(Figures are in natural size)

Orthotetina eusarkos (ABICH) subsp. *lata* HAYASAKA.

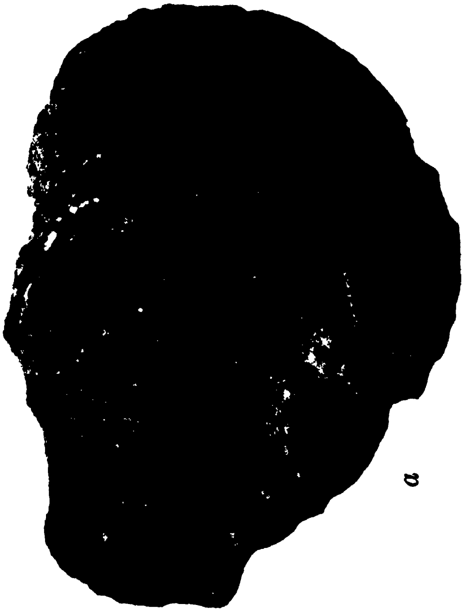
The only specimen in my collection. By polishing down the tip of the beak the characteristic dental structure has been examined. *a,* dorsal view; *b,* ventral view; *c,* posterior view, showing the development of a low triangular cardinal area in the ventral valve; *d,* anterior view showing the asymmetrical curve made by the shell junction.



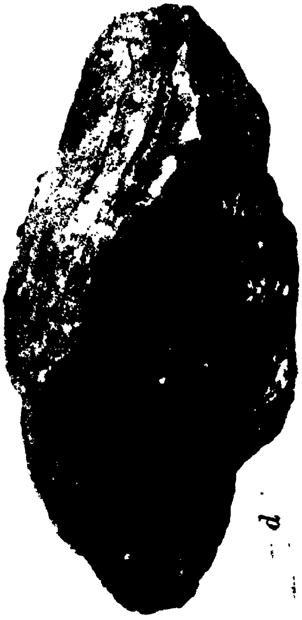
b



c



a



d

Explanation of Plate XIV.

(All the figures are in natural size)

Fig. 1. *Spirifer acutiplicatus* HAYASAKA. Specimen No. 1 (**Holotype**). A dorsal view.

Fig. 2. *Spirifer acutiplicatus* HAYASAKA. Specimen No. 2: *a*, ventral view; *b*, anterior view.

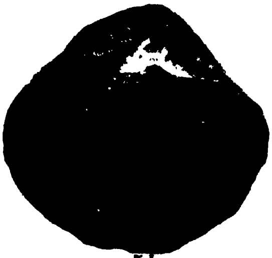
Fig. 3. *Spirifer acutiplicatus* HAYASAKA. Specimen No. 4: A fragmentary dorsal valve.

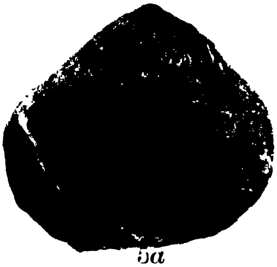
Fig. 4. *Spirifer acutiplicatus* HAYASAKA (?). Specimen No. 5. Plication is somewhat different from other specimens. This may be anthor species.

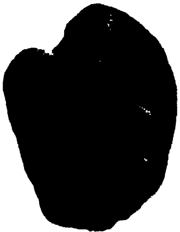
(For *Spirifer acutiplicatus*, see also Fig. 3, Pl. VIII.)

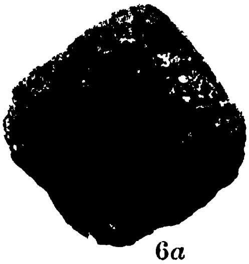
Fig. 5. *Martinia* sp. A more or less rounded specimen. *a*, dorsal view; *b*, ventral view; *c*, lateral view.

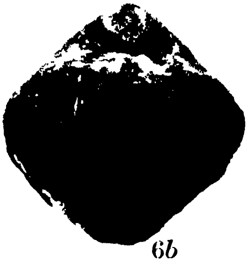
Fig. 6. *Martinica* sp. Another, roundly trapezoidal specimen. *a*, dorsal view; *b*, ventral view; lateral view.

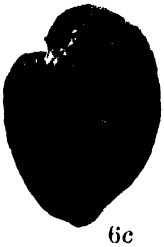

5*b*


5*a*

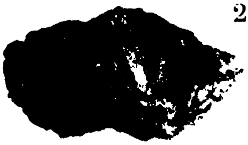

5*c*


6*a*

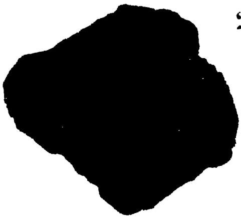

6*b*


6*c*

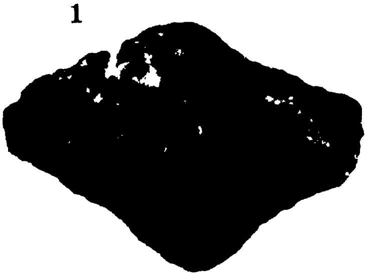
2*b*



2*a*



1



4

3

BEDDED HEMATITE DEPOSITS OF THE RIGEN MINE, S. KANKYÔ-DÔ, CHÔSEN (KOREA)

With 6 Text-Figures and 3 Plates (XV-XVII).

By

Takeshi ICHIMURA.

(Accepted for publication, April 13th, 1933)

CONTENTS

Introduction 45
Location of Area 46
Topographical and Geological Features. 47
The Occurrence and Nature of the Hematite Deposits.... 51
The General Features of the Ores.... 52
Microscopical Characteristics of the Ores. 53
Chemical Composition of the Ores. 55
The Chlorite Vein, Micaceous Rock and Leached Quartzite
Associated with the Hematite Deposits. 55
Origin of the Ore-deposits. 57
A Consideration Concerning the Banded Structure of the Ores. 60
Original Source of the Iron Ores. 61
Summary. 62

INTRODUCTION.

There is an isolated exposure of the so-called Chôsen System at the southern end of the granite area including three counties, of Hokusei (北青), Tansen (端川) and Rigen (利原) of S. Kankyô-dô (Fig.

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VI, No. 3, June, 1933.]

1). This formation is sometimes intercalated by the bedded hematite deposits which are particularly thickened at the Rigen Mine. The mine here has hitherto been deeply excavated by the underground working and open-cut with an abundant annual production of ores. It is one of the most important iron mines of Korea at present.

The present paper embodies the results of some geological investigations carried out by the writer several years ago. The writer is much indebted to the manager and mining engineers of this mine.

LOCATION OF AREA.

The Rigen Mine is located along the valley extending north from

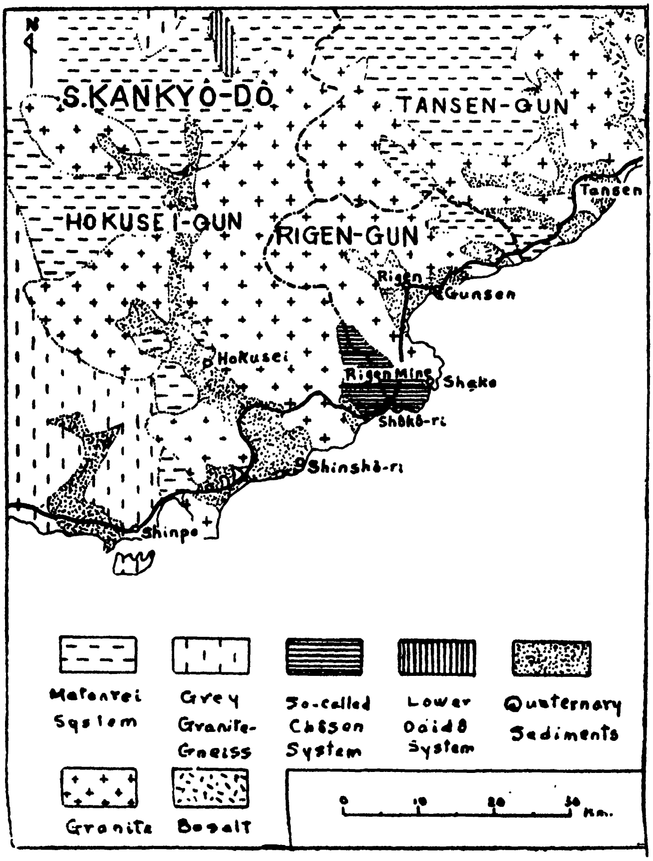


Fig. 1.
Geological map of a part of S. Kankyô-dô including the Rigem Mine.

the small village called Shôkô-ri (昌興里) of Nan-men (南面), Rigen-gun (Fig. 2). The nearest town is Shako (遮湖) which has a small but a good harbour, about eight kilometers east of this mine. It is situated approximately in the southwestern corner of the area enclosed by the parallels 40° 10′ and 40° 20′ N, and the meridians 128° 30′ and 128° 45′ E. The mine is only three kilometers from the coast of the Sea of Japan and has been recently much facilitated by the extension of the Kankyô (咸鏡) line between Genzan (元山) and Kainei (會寧).

TOPOGRAPHICAL AND GEOLOGICAL FEATURES.

The area surrounding the mine is very deeply dissected topographically. All ridges are extended from north to south and sometimes rise up to narrow ridges, more than 500 meters above sea-level. Some of them end abruptly near the sea without any coastal plain (Fig. 2).

It is mostly made up of the so-called Chôsen System isolated by the enormous exposure of the granitic mass and is covered by Quaternary sediments (Fig. 3).

The so-called Chôsen System exposed here consists of quartzite, chloritoid-sericite slate, biotite-sericite slate, tourmaline-bearing sericite slate, hematite bed, etc.

(I) **Quartzite Zone**:—Quartzite is the most predominant rock which has varying colors. Greyish white and light brown varieties are commonly found. It occurs in the lower horizon of the formation and is beautifully stratified, showing a strike of N 60°–70° W and a dip of 50° SW or thereabouts. Such quartzite beds are frequently intercalated by the lenses of talc deposits1), large or small. Sometimes the occurrence of remarkable ripplemarks is found in this rock. Under the microscope it is a granular aggregate of interdented quartz in association with sericite, magnetite, hematite, limonite, zircon and feldspar. Quartz is

---

1) There are many small talc deposits at various horizons of quartzite. They are always found in irregular masses parallel to the stratification plane. These lenses are often more than four meters in the thickest part. The talc here has usually a light greenish color due to the presence of some impurities. It often shows a banded structure along the hanging wall where the lenses are sharply bordered by the country rock. They were prospected in several places, but are not of economic value.

characterized by a conspicuous strain-shadow as well as innumerable minute liquid inclusions.

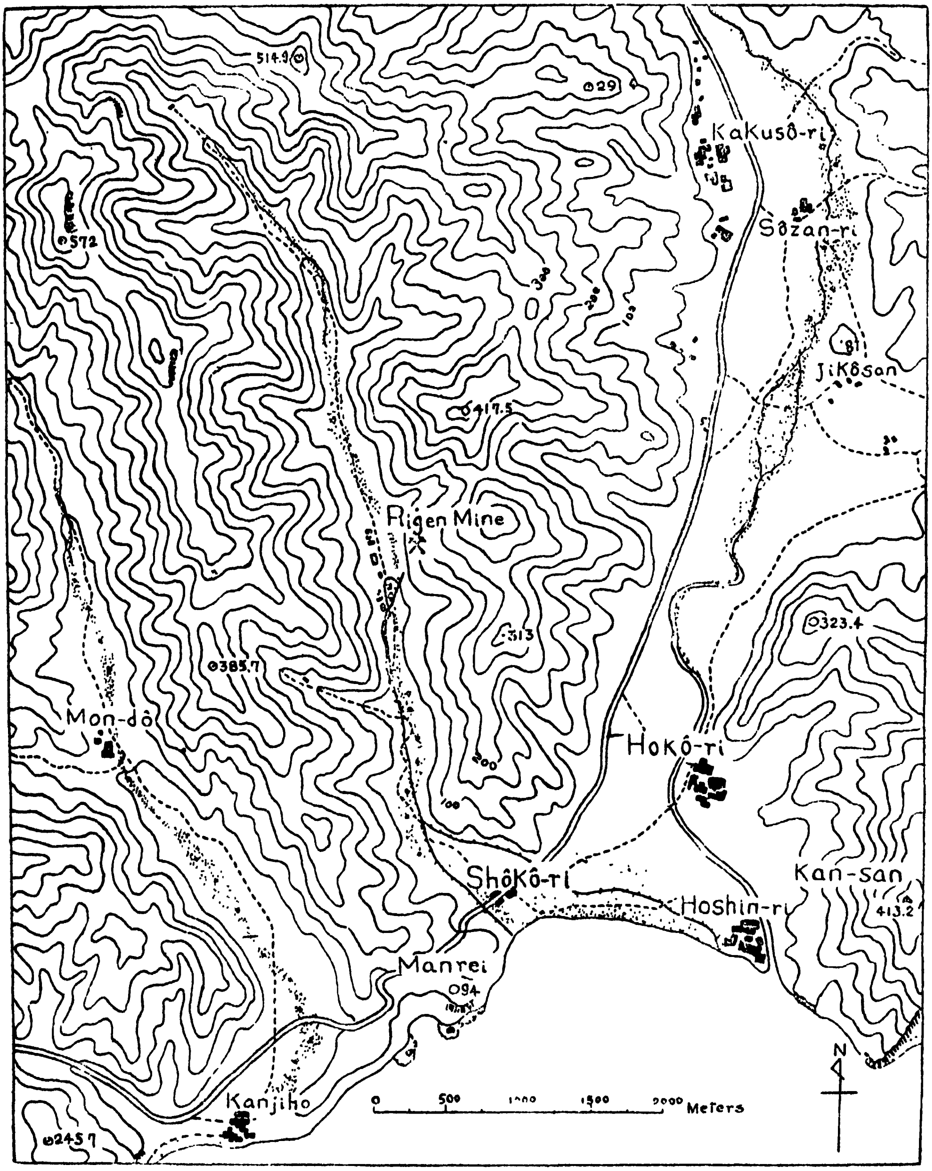


Fig. 2.
Topographical map of the Rigen Mine and vicinity.

(II) Slate Zone :—Slaty rocks are to be seen in the upper horizon of the formation. They are well exposed in the southern half of the area, showing a gradual transition between them.

(i) **Chloritoid-sericite slate:** The most interesting rock is a chloritoid-sericite slate which is abundantly found in this zone. It is usually a thinly cleavable and somewhat spotted rock with a bluish grey or dark grey color. Besides chloritoid, the rock is composed of sericite, tourmaline, rutile, magnetite, quartz, limonite, carbonaceous matter, etc.

Chloritoid[1] crystals (Pl. XVII, Figs. 1–2) occur generally in the form of independent tabular flakes or of tufts which are megascopically disseminated as micaceous spots. It shows a following weak pleochroism, viz., X=light greenish yellow, Y=light blue, Z=nearly colorless. The absorption is $Y>X>Z$, and the mineral character is positive. Its extinction angle, $Z\wedge c$, is 13° or thereabouts. The index of refraction is measured as follows: $N_m=1.721$. The double refraction color is very low. The cleavage parallel with (001) is distinctly observed and the basal section shows mostly an indistinctly rounded outline and imperfect cleavage intersecting at an angle of about 60°. Polysynthetic twin on (001) is commonly remarkable, being often associated with a penetration twin. Chloritoid is arranged in random directions and there are some evidences that this mineral is often somewhat rotated after its formation. Another characteristic is that a minute scaly sericite is abundantly found together with chloritoid. Polygonal quartz is the most abundant constituent, whereas tourmaline, rutile, magnetite, limonite and carbonaceous matter are only accessorily present. The chloritoid bearing rock shows a beautiful banded structure in the transition stage from quartzite. In this case the white band consists mainly of quartz in association with a small amount of chloritoid, sericite, tourmaline, rutile, magnetite, etc., while the black part is a confused aggregate of abundant chloritoid and sericite together with quartz and other accessory minerals.

(ii) **Biotite-sericite slate:**—The rock is alternately bedded with chloritoid slate. It is a banded rock with a dark grey color of a somewhat fresh appearance, but also having a reddish brown color as those of severely

---

[1] This mineral is free from the manganese content, and therefore, it is not ottrelite, although other characters are similar

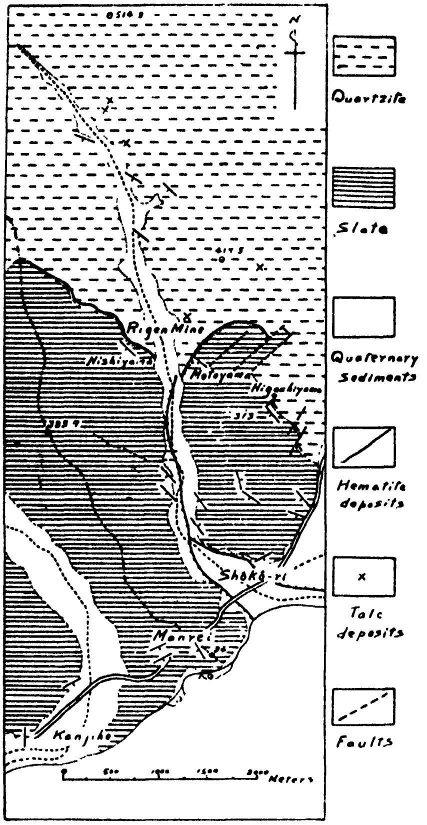


Fig. 3.
Geological map of the Rigen Mine and vicinity.

weathered ones. The constituent minerals are biotite, sericite, tourmaline, magnetite, quartz, rutile, chlorite, etc. Biotite takes a tabular form and is partly altered to chlorite. Sericite is ingrained all over the rock in fine aggregates with quartz. Tourmaline is more common than in the chloritoid slate. This mineral is found mostly in small prismatic or granular forms, indicating a characteristic pleochroism, from light brown or colorless (X) to bluish brown or bluish grey (Z).

(iii) Tourmaline-bearing sericite slate :—The chloritoid slate often changes into phyllitic rock with a bluish grey color. Such a rock can be seen on Man-rei (蔓嶺) between Kanjiho (乾自浦) and Shôkô-ri. The chief characteristic of it is the abundant occurrence of tourmaline together with sericite. Besides these, quartz, magnetite, zircon, carbonaceous matter, etc. are to be seen. Tourmaline is usually long prismatic or stout prismatic in its crystal form. A six-sided basal section is very common. It has typical traversing prismatic cracks and also a strong pleochroism, viz., X=colorless, Z=yellowish brown with locally bluish shade.

The rocks of the slate zone are more intensely disturbed than the quartzite. Some of them are repeatedly displaced by parallel faults, as is shown in the vicinity of the hematite deposits. The beds along the route between Kanjiho and Shôkô-ri are also much disturbed.

(III) The Geological Age of the so-called Chôsen System :—It seems that the formation was accumulated later than the enormous intrusion of granite which is widely exposed outside the writer's field. KAWASAKI[1] also states that it rests unconformably upon the red granite which includes various xenoliths of metamorphic rocks derived from the Matenrei System, The unusual occurrence of chloritoid, sericite, biotite, etc. in slaty rocks is probably due to the dynamical metamorphism, and there is none of such characteristic contact minerals as andalusite, chiastolite, cyanite, staurolite, etc. in the writer's specimens. The geological age of this formation can not exactly be identified, but it has many similarities to the Cambrian (?) of other regions.

(IV) **Granite**:—The granite of this region belongs to the biotite or both biotite and hornblende-bearing varieties with a coarsely granular texture. They can be seen on the pass between Heiri (坪里) and Kanjiho and also in the hilly area near Shako.

THE OCCURRENCE AND NATURE OF THE HEMATITE DEPOSITS.

The hematite deposits are found both in quartzite and slate zones, occurring in bedded forms at two horizons. One of them is intercalated between quartzite beds near the transition zone to slate, while the other belongs to a still upper horizon. The lower hematite bed is traceable for nearly 8 kilometers from the Hôgan (寶巖) Mine to Kansan (官山), crossing the Rigen Mine, it being the only source of ores at present. The hematite bed here shows a strike of N 50°–70° W and a dip of 28°–40° SW. Its exposure is separated into two parts, east and west, by the transverse valley extending north from Shôkô-ri, traversing diagonally the slope of the valley side. The eastern exposure surrounds the steep slope of Motoyama (本山-Pl. XV, Fig. 1) and extends about 1,200 meters to Higashiyama (東山) where it is repeatedly displaced by small parallel faults. Such a fragmentary exposure can be traceable further southward. The displacement of the hematite bed may distinctly be observed in the adits of Motoyama. It is cut by many parallel faults

---

1) S. KAWASAKI: Mica in Chôsen, Bull. Min. Surv. Chôsen, Vol. 1, Part. 2, p. 40, 1910. The geological age of the Matenrei system is identified wich the Pre-Cambrian.

mostly running from northeast to southwest and is displaced from 2 meters to 3.5 meters vertically. This is also a tendency seen at Higashiyama.

The western exposure is, on the other hand, slightly excavated, and it is continuous from the bottom of the valley up to the summit of the ridge without any conspicuous disturbance. Its probable length is about 2,000 meters along the slope called Nishiyama (西山–Pl. XV. Fig. 2). The bed crosses the ridge in this place and again appears on the other side, extending to the Hôgan Mine.

The thickest portion of the bed may be noticed at Motoyama where the maximum thickness is 6.2 meters in the adit and about 6 meters at the eastern end of the exposure (Pl. XVI. Fig. 1). It is also 3.6 meters and 1.5 meters respectively at two outcrops of Higashiyama. The bed is, however, thinner at Nishiyama and there it does not exceed 3.3 meters in the maximum thickness.

This bed frequently shows a distinctly banded structure, changing either sharply or gradually into a grey quartzite. Some good examples are noticeable along the exposure of Higashiyama and Nishiyama. Sometimes quartz lenses of various sizes are included in the hematite bed, and quartzite is, on the other hand, separated by thin hematite striations along bedding planes, as is commonly observed at several places at Nishiyama.

The upper hematite bed occurs in very small scale on the slope, about 1,500 meters northeast from the Shôkô-ri village. It is of no economic value.

GENERAL FEATURES OF THE ORES.

There are several types of ores with a gradual transition in different places of this mine. The most predominant is a hard micaceous hematite ore with a fine granular feature. It is somewhat easily cleavable along the bedding plane and locally passes into a soft micaceous variety, particularly in the neighbourhood of the hanging wall. The soft micaceous hematite ore is not infrequently seen in adits No. 9 and No. 10 of Motoyama. It can readily be crushed between fingers. Hematite is often mixed with abundant quartz and it looks like a hematite sandstone or quartzite. Sometimes the ores are the granular aggregates of coarse hematite crystals which often give a mottled appearance together with quartz. Such specimens can be obtained from the adit No. 6. Some of the hematite ores are severely subjected to shearing and exhibit a much distorted surface. Ordinary ores here are more or less banded with the parallel arrangement of quartz layers. The ores called "Tora" (tiger) are irregularly banded types due to the presence of quartz lenses (Pl. XVI, Fig. 2).

MICROSCOPICAL CHARACTERISTICS OF THE ORES.

The ores are composed of hematite, magnetite, quartz, sericite, tourmaline, chlorite, etc.

Hematite usually occurs in a confused mozaic aggregate of tabular or polygonal crystals in thin section, being cemented by quartz and other minerals. The single crystals occasionally show hexagonal or rhombic sections, which are sometimes transparent and are also characterized by a blood red color with a weak pleochroism. In the polished section hematite gives a white color as well as a shining pitted surface, being often characterized by a flaky aggregate (Pl. XVII, Fig. 4). There are various gradations between ores and hema-

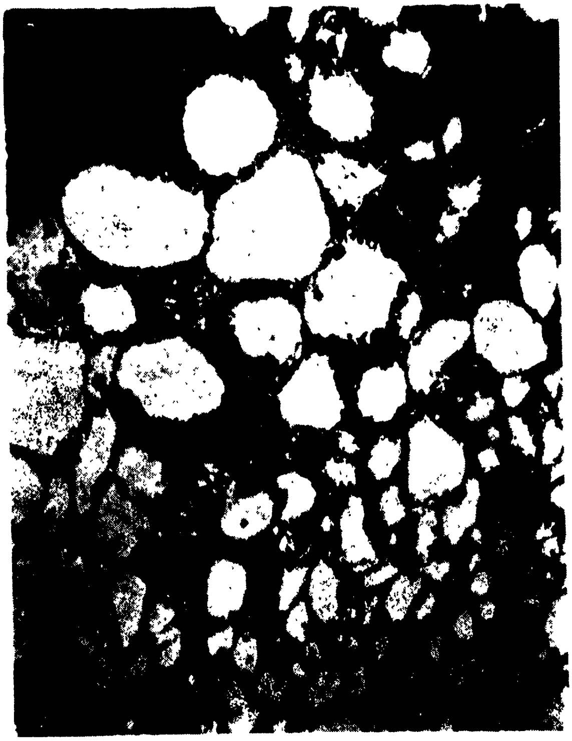


Fig. 4.
Network pattern of hematite (black). The grey part is quartz. ×20.

tite quartzite. In the low grade ores hematite is intersticially found between quartz grains and forms broken lines or chains around them. They are sometimes connected each other, and a network pattern (Fig. 4; Pl XVII, Fig. 3) is made in various ways. Sometimes hematite shows a zonal arrangement together with quartz (Fig. 5). It is, however, entirely obscured by the increase of hematite. In such a condition the hematite mass includes sporadical dots of quartz grains with complicately crenated edges.

Since the ores are more or less sheared, a remarkable undulatory extinction is usually observed in recrystallized quartz grains. The interstices of large grains are often filled up by somewhat argillaceous materials. Sericite is abundantly formed in such parts, particularly in low grade ores or hematite quartzites. It takes flaky or tabular crystal forms and shows occasionally a radial arrangement around large quartz grains. In some specimens chlorite is more common than sericite. Sometimes its flaky crystal has distinct cleavages parallel with (001) and is pleochroic as follows: X=light yellow, Y=Z=light green.

Besides these minerals, granular tourmaline and apatite are rarely known in low grade ores. The occurrence of tourmaline is, however,

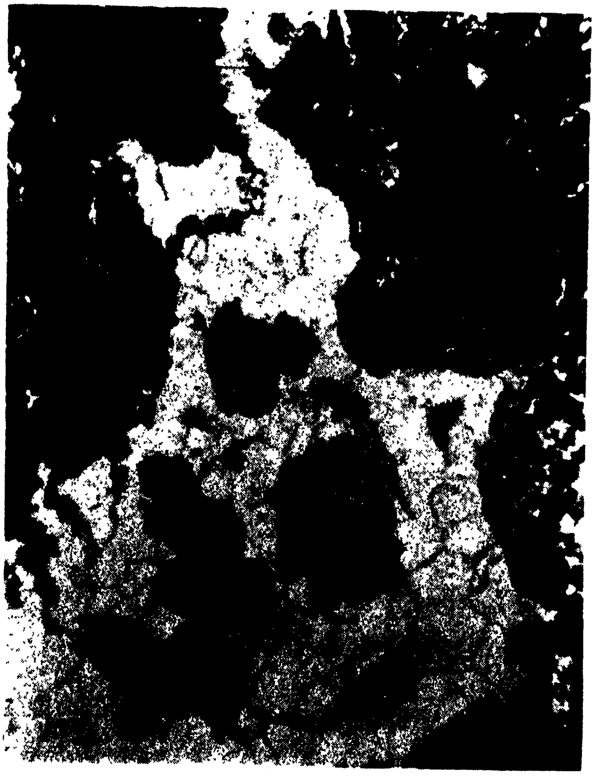


Fig. 5.
Zonal arrangement of hematite (black) and quartz (grey). ×20.

very common in the magnetite-hematite-bearing quartzite associated with the hematite bed. It is characterized by a strong pleochroism from yellowish grey to dark blue with the following indices of refraction, viz., No=1.651, Ne=1.628. Apatite is especially observed in chlorite-bearing ores, including minute hematite or sericite crystals in it.

CHEMICAL COMPOSITION OF THE ORES.

There are various transition stages from hematite quartzite to ores. Even high grade ores are often alternately banded with thin quartz layers. Thus, the most characteristic feature of the chemical composition is the abundance of silica. As will be understood from the following results of the chemical analysis, the ores are usually low in sulphur and high in phosphorus. The amount of Fe seems to be a little higher than 54 per cent in the ores of average value. Some of these examples are shown in the following table.

	(1)	(2)	(3)	(4)	(5)
Fe	61.92	58.46	54.56	54.06	54.21
SiO_2	9.97	12.43	17.47	17.48	18.22
S	0.01	0.03	tr.	tr.	tr.
P	0.10	0.15	0.131	0.132	0.130
Mn	0.06		0.06	0.05	0.05
Cu			0.001	0.001	tr.

(1), (2), (3), (4) and (5) Hematite ores from Motoyama. Analysed at the Muroran Steel Works.

THE CHLORITE VEIN, MICACEOUS ROCK AND LEACHED QUARTZITE ASSOCIATED WITH THE HEMATITE DEPOSITS.

The hematite bed is sometimes associated with the chlorite vein, micaceous rock and leached quartzite. Among them the chlorite vein is undoubtedly a hydrothermal product, later than the formation of hematite deposits.

(1) The occurrence of the chlorite vein is quite local in the adit No. 8 of Motoyama. Here it fills up the space along the fault plane between the hematite and the quartzite beds. The vein is highly inclined, the broadest part of it being more than two meters. Quartzite is remarkably sheared along the contact, and this zone is severely subjected both to chloritization and pyritization. In hand specimens the vein stuff has a dark greyish green color, being characterized by the conspicuous dissemination of pyrite and hematite crystals (Fig. 6).

Chlorite occurs in a single flaky form or in a confused aggregate. The crystal has a perfect cleavage parallel with (001), and it shows a helicoidal structure due to shearing. It is slightly pleochroic in the thin section except the base, viz., $X=Y=$pale green, $Z=$pale yellow. The index of refraction is $N_m=1.605$, and it is optically positive. The optic angle is nearly zero or very small. Hence this chlorite may belong to clinochlore.

Most of the pyrite crystals are closely associated with chlorite flakes. They have mostly a complicated outline, although there are sometimes crystals with a sharp cubic habit. Hematite is present in less amount than pyrite. When both minerals are associated together, the pyrite is penetrated by hematite, indicating that the former was crystalized a little earlier than the latter. Pyrite is more likely to alter into limonite than hematite.

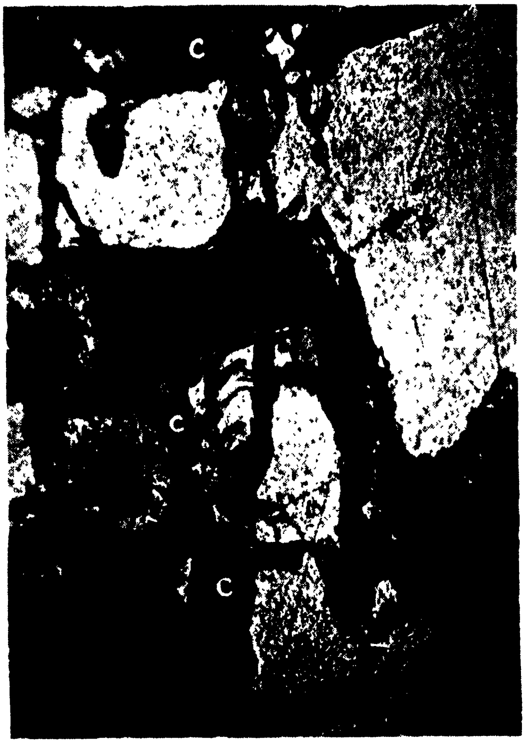


Fig. 6.
Hematite and pyrite in the chlorite vein.
C=Chlorite, H=Hematite, P=Pyrite. ×30.

Besides these, the prominent mineral is the quartz which fills up the interstices of the above mentioned minerals. A conspicuous strain shadow can be seen in almost all the grains. The quartz sometimes includes minute grains of an unknown colorless mineral with a high index of refraction and high birefringence.

In association with chlorite and quartz there is a colorless mineral identical with zoisite. This mineral always occurs in a granular form with somewhat of a shagreen surface, having a very low birefringence as well as a much higher indices of refraction than quartz and chlorite. It is undoubtedly biaxial, and the mineral character is positive. Distinct cleavages parallel with (010) are well seen : the extinction is straight.

(2) In the adit No. 7, a micaceous rock is intercalated between hematite layers displaced by a fault. It is 18–40 cm. in thickness, occurring usually in very loose masses which are often traversed by many hematite stringers and films. The rock mainly consists of muscovite, quartz and hematite.

Muscovite is the most abundant mineral in this rock. It is always found in flaky forms or confused aggregates. The crystal is generally 0.3 mm. to 0.7 mm. in the basal diameter. A distinct basal cleavage and a high birefringence are very characteristic to this mineral. Sometimes these flakes are extremely twisted and are traversed by cracks which are filled up by limonite.

Hematite is abundant in close association with muscovite, occurring in platy or irregular forms. Its mode of occurrence indicates that this mineral and muscovite were almost simultaneously crystallized.

Quartz fills up the interstices of other ingredients. The crystal form is polygonal and it is found in a mozaic aggregate. Limonite is a secondary mineral derived from hematite.

(3) Besides these, there is a spongy rock with a white color in this vicinity. It is only composed of quartz and is undoubtedly altered from quartzite by the partial leaching of silica, as shown by various stages of transition between them.

ORIGIN OF THE ORE-DEPOSITS.

It is also remarkable that many bedded deposits of iron ores are known in the oldest formations of Korea and Manchuria. Some of them are more or less similar to those of the Lake Superior regions as well as of Itabira de Matto Dentro, which are attributed to be of sedimentary origin. They are mostly built up of low grade ores with a banded structure, being often intercalated by enriched ore bodies. The ores are usually composed of both hematite and magnetite, or magnetite only in association with abundant quartz. Thus, banded ores gradually pass into magnetite-hematite quartzite or magnetite quartzite. Besides quartz, some of them contain amphiboles or feldspars. On account of the absolute absence of such iron minerals as siderite or greenalite, it is very hard to determine whether these deposits are really of sedimentary origin, or of metasomatic origin.1) Although there are diverse hypotheses about them, their modes of occurence, mineral or chemical compositions of ores, indicate that some of them were originally deposited as chemical sediments. The sedimentary hypothesis was already proposed by H. MURAKAMI2) and I. KOMADA.3) The writer4) also disccussed about such types of deposits in his paper written in Japanese.

As to the genesis of hematite deposits of the Rigen Mine only a little has been known up to the present, the only paper being the writer's preliminary note.5) The ore bodies here are always found in a

---

1) S. KAWASAKI states that the so-called Pre-Cambrian banded iron ores of Korea were formed under the metasomatic process (S. KAWASAKI :—The Distribution of Iron Ores in Korea, Jour. Korean Min. Assoc., Vol. 2, 1919, p. 11). The similar consideration seems also to be maintained by T. HIRABAYASHI. However, the iron ore formations of Korea and Manchuria are found in a large extension and they are usually highly quartzose without any calcareous part in them. There is no relic of the original rock, which would be expected, if the iron ore formation were of metasomatic origin. In the Rigen Mine hematite deposits are quite free from the intrusion of igneous rocks. The granite exposed in this region is probably an earlier intrusion than the so-called Chôsen System. Although the hematite bed is locally traversed by the chlorite vein they are genetically indifferent.

2) H. MURAKAMI: The Iron Ore Deposits of Si An-shan, S. Manchuria, (in Japanese), Jour. Geol. Soc. Tôkyô, Vol. 26, 1919, pp. 422–423; Geology of the An-shan Iron Mine District, S. Manchuria, 1922, pp. 29–33.

3) I. KOMADA: On the Pre-Cambrian Formation in the Vicinity of Chûshû, N. Chûsei-dô; the Geology and Origin of Ore Deposits of the Chûshû Iron Mine (in Japanese), Jour. Korean Min. Assoc., Vol. 5, 1922, pp. 389–394.

4) T. ICHIMURA: Koreo-Manchurian Pre-Cambrian Banded Iron Ore Deposits and Their Enriched Ore Bodies (in Japanese), Jour. Geol. Soc. Tôkyô, Vol. 28, 1921, pp. 243–247.

5) T. ICHIMURA: The Rigen Iron Mine (in Japanese), Jour. Korean Min. Assoc., Vol. 9, 1926, pp. 109–128.

bedded form and usually grade into quartzite or slate, the amount of hematite and sericite decreasing gradually.

There are also banded ores due to the presence of innumerable thin quarts layers, and some of them are quite similar to those of the so-called Pre-Cambrian iron ore deposits. However, banded ores as well as massive types are commonly associated with sericite and highly sheared quartz. The sericite was recrystallized from argillaceous materials, as shown by the close association with chloritoid common in slate. The ores are thus entirely recrystallized to hematite without any trace of the primary iron ore minerals.

Geologically the so-called Chôsen System exposed here is built up of quartzite and slate zones, hematite beds being intercalated in both of them. The lower hematite bed is particularly well banded and its thickness is almost uniform for a long distance. Some of the ores indicate a somewhat sandy texture. The hematite bed seems to be a sedimentary facies of quartzite which is particularly enriched by ferruginous and argillaceous materials. The high percentage of · phosphorus in the ores also seems to suggest the validity of this conclusion.

There are at least two main hypotheses concerning the sedimentary origin of such ores, viz., mechanical and chemical. The former was taken up by I. KOMADA,¹⁾ whereas the latter was adhered to by H. MURAKAMI.²⁾ KOMADA studied the Chûshû Mine in N. Chûseidô of Korea. There the ores are massive, and are composed of hematite and magnetite. They are found between biotite granite upwards and sandy mica gneiss downwards. He considered that the primary ores were magnetite concentrated mechanically as magnetite sands, and that they were partly altered to hematite by the influence of a dynamo-metamorphism. The magnetite sand is generally more or less titaniferous, but unfortunately he did not test the titanium content of the ores.

MURAKAMI discussed the genesis of the An-shan iron ore deposits. He states that there are many similarities between those of An-shan and the Lake Superior or Minas Geraes ores. In spite of the absolute

---

1) Op. cit. pp. 391-392.

2) H. MURAKAMI: Geology of the An-shan Iron Mine District, S. Manchuria, p. 53.

absence of primary iron ore minerals, he supposed them to have chiefly been hydrous iron oxide with some amount of siderite precipitated by a biochemical process. It has the same tendency as those of **GRUNER** and **GROUTS'** hypotheses[1] in which they attributed the primary minerals of the Lake Superior ores to be siderite, greenalite, limonite, etc., similarly precipicated by a biochemical process.

As will be inferred from the frequent presence of ripple marks, the quartzite here was not originally formed under very deep water. As the rock is wholly recrystallized at present, it is not obvious whether the quartzite was formerly sand, or whether it was partly a precipitation product of colloidal silica, but the structure of some quartz granules in the alumina-iron-rich variety seems to indicate the previous colloidal condition of the rock. The same is observed in the hematite ores.

Ferric hydroxide thus precipitated is probably later recrystallized to the hematite, and alumina-rich portions similarly passed into sericite under the influence of the dynamic metamorphism.

A CONSIDERATION CONCERNING THE BANDED STRUCTURE OF THE ORES.

One of the most noteworthy points of these ores is the presence of the banded structure. A further consideration is necessary on the process of such a characteristic precipitation. The writer[2] already considered it to be a rhythmic precipitation from the colloidal solution of iron and silica. At that time the writer quotated **LIESEGANG'S** diffusion theory. As shown in E. S. **MOORE** and J. E. **MAYNARDS'** recent paper,[3] the pecipitation of banded iron and silica can be expected in the laboratory by the diffusion of a soluble hydroxide into a silica gel. They state about it as follow," . . . . Ferric hydroxide is precipitated in a few days when colloidal solutions, containing iron and silica stabilized by organic matter, are subjected to the influence of electrolytes of the kind and concentration found in the sea, whereas the silica coagulated after several months. This result suggested that if a fresh supply of material were added the process would be repeated, giving a banded structure, and such was found to be the case." Having investigated the Miao-erh-kou Mine of S. Manchuria, K. TSURU[1] considers that the structure of the ores seems to have been formed by the different precipitating velocities of the sols of silica and ferric hydroxide. However, the precipitation of Koreo-Manchurian banded iron ores is inferred to have been more complicated, particularly in large iron formations, being influenced by various physico-chemical conditions. Such a structure, on an enormous scale, is not probably due to the metasomatism of the originally banded rock.

---

[1] F. F. **GROUT**: The Nature of Origin of the Biwabik Iron-bearing Formation of the Mesabi Range, Minnesota, Eco. Geol., Vol. 14, 1919, pp. 452-464.
J. W. **GRUNER**: The Origin of Sedimentary Iron Formation: The Biwabik Formation of Mesabi Range. Eco. Geol. Vol. 17; 1922, p. 435.

[2] Op. cit. Jour. Geol. soc. Tôkyô, Vol. 28, 1921, pp. 246-247.

[3] E. S. **MOORE** and J. E. **MAYNARD**: Solution, Transportation, and Precipitation of Iron and Silica, Eco. Geol., Vol. 24, 1929, pp. 285-286.

ORIGINAL SOURCE OF THE IRON ORES.

So far as has been investigated, it is quite unknown where the real source of the Rigen iron ores is. The evidence for such hypotheses as were proposed by Van HISE[2] and C. K. LEITH[3] regarding the source of the Lake Superior iron formations can not be expected within the writer's field under consideration. MOORE, MURAKAMI, and others also suppose that a large amount of iron was extracted from weathered rocks during a long period of surface erosion.

In the Rigen Mine district the so-called Chôsen System is the only isolated remnant in the enormous granite mass, being indifferently exposed from the Matenrei System identified by S. KAWASAKI[4] with the Pre-Cambrian. The intrusion of the granitic masses is hitherto considered to be later than that of the Matenrei System, which seems, according to KAWASAKI, also to be older than gray granite-gneiss dis-

---

1) K. TSURU: Geology and Ore Deposits of the Miao-erh-kou Iron Mine District, Rep. Ryojun Coll. Eng., Vol. 1, No. 3, 1931, p. 196.

2) W. LINDGREN: Mineral Deposits, 1928, p. 416.

3) C. K. LEITH: Iron Ores of Canada, Eco. Geol., Vol. 3, 1908, pp. 276-291.

4) S. KAWASAKI: Mica in Chôsen, Bull. Min. Surv. Chôsen, Vol. 1, part 2, 1916. pp. 39-40.

tributed extensively in Korea. Although the so-called Chôsen System is absolutely free from fossils, its geological age is believed to be younger than that of the Matenrei System. In this way it would not be denied that there were elsewhere some older formations or igneous rocks that were the source of such iron ores.

SUMMARY.

(1) The so-called Chôsen System exposed isolatedly in the Rigen Mine district is chiefly made up of a thick accumulation of quartzite and slate, intercalated by hematite deposits.

(2) The hematite deposits here are found in bedded forms at two horizons, showing usually a gradual transition to quartzite and slate. The main ore body occurs in the uppermost horizon of the quartzite zone where it is traceable for nearly 8 kilometers from the Hôgan Mine, crossing the Rigen Mine, to Kansan. It is the present source of the ores of the Rigen Mine. The other ore body is of a much smaller scale.

(3) There are various kinds of hematite ores with a gradual transition between them. The most common ores are the massive and banded varieties which are usually composed of micaceous hematite, quartz, and sericite.

(4) Chemically, the iron ores are generally low in sulphur, but high in phosphorus.

(5) There are some evidences of the hydrothermal process, but it does not seem to have any influence upon the genesis of ore bodies.

(6) Although there is no trace of primary ore minerals, hematite ores may be the recrystallized products from them.

(7) Such primary iron ore minerals were a facies of sedimentation, probably due to a chemical process.

(8) The hematite is always associated with alumina-rich parts of quartzite in which the structure of some quartz grains seems to indicate some colloidal conditions.

(9) The banded structure is one of the most significant features of the Rigen ores. It will be expected in a rhythmic precipitation from

the colloidal solution of iron and silica.

(10) In this way the iron ores are considered to have been precipitated originally as a hydrous oxide which was derived by the weathering agency from some older formations. It was later recrystallized to the hematite under the influence of the dynamical metamorphism.

PLATE XV.

Explanation of Plate XV.

Fig. 1. Motoyama looking from Nishiyama. The hematite bed diagonally traverses the steep slope of the valley side. Its position is shown by a chain-like arrangement of many adits. It is found at the uppermost horizon of quartzite.

Fig. 2. Nishiyama looking from Motoyama.

1

2

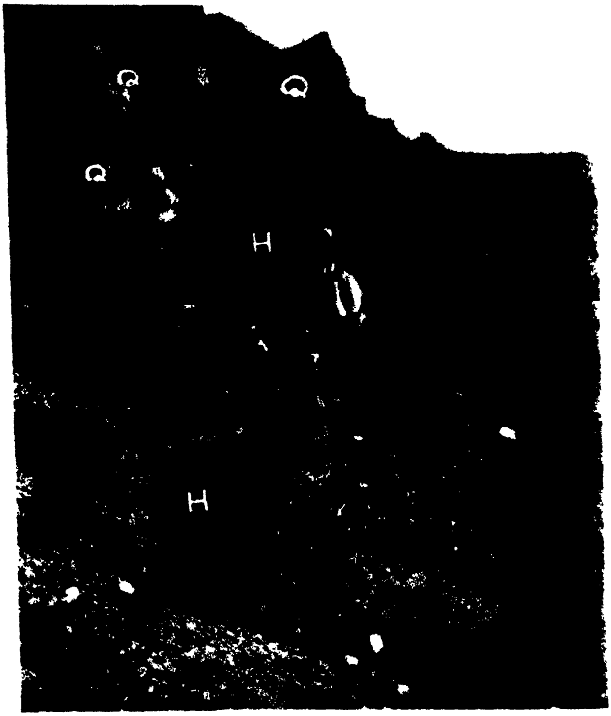
PLATE XVI.

Explanation of Plate XVI.

Fig. 1. An outcrop at the eastern end of Motoyama.

H = Hematite bed, Q = Quartzite.

Fig. 2. A characteristic ore called "Tora". The white patches in the hematite mass are quartz.



1

2

PLATE XVII.

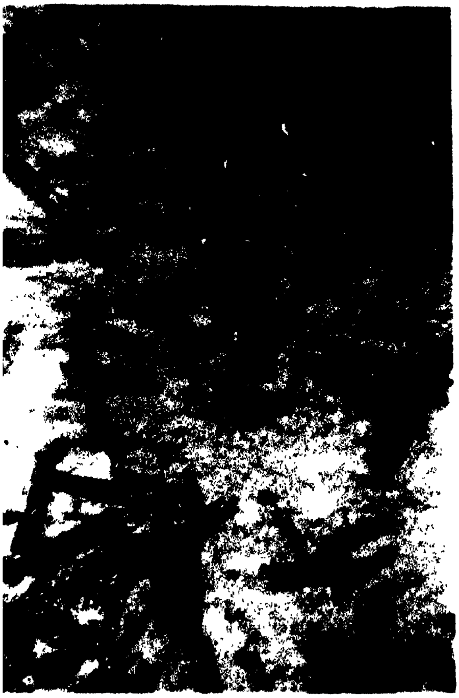
Explanation of Plate XVII.

Fig. 1. Chloritoid-sericite slate. The tabular crystals are chloritoid. The other part is composed of sericite, tourmaline, rutile, magnetite, quartz, carbonaceous matter, etc. × 20

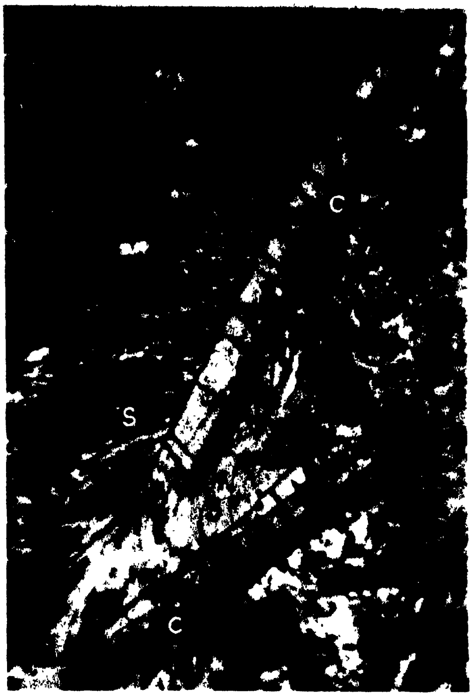
Fig. 2. Chloritoid crystals surrounded by a confused aggregate of sericite.
C = Chloritoid, S = Sericite, quartz, etc. × 60

Fig. 3. A network pattern of hematite.
H = Hematite, Q = Quartz, S = Sericite. × 80.

Fig. 4. A flaky aggregate of hematite crystals. × 30.

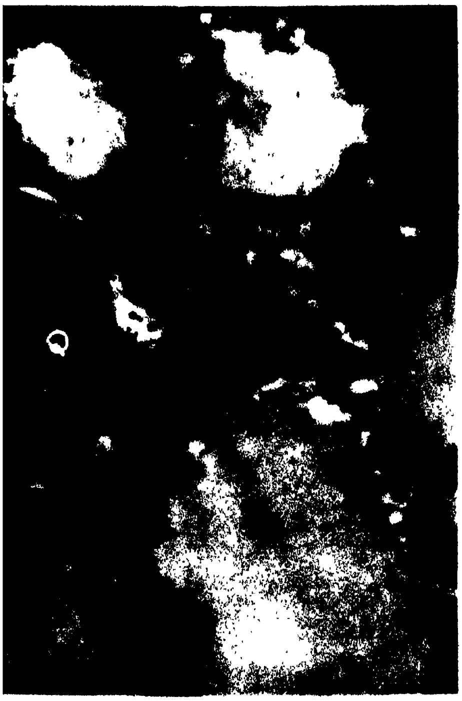


1

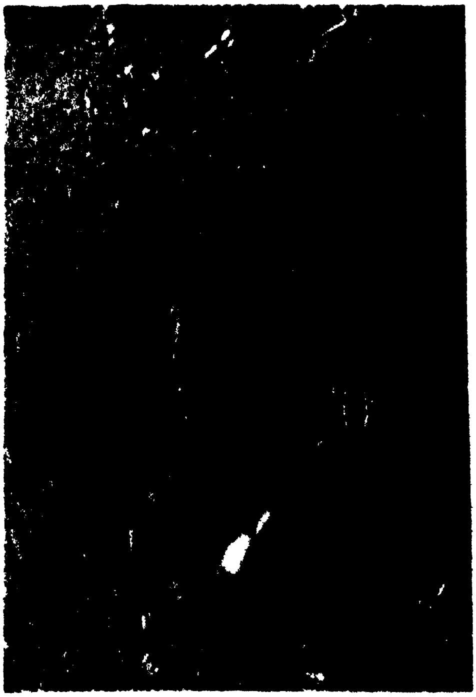


2

3



4



Fossil Occurrence of Pelecypod Shells Bored by Certain Gastropods.

With Plates I [XVIII]-IV [XXI].

By

Ichirô HAYASAKA.

(Accepted for publication, June 8, 1933)

I. Fossil occurrence of pelecypod shells with holes bored by gastropods of prey is by no means uncommon. This paper will not be limited, however, merely to the description of examples of such fossils.

On examining fossil shells found in the substratum of the campus of the Tainan Technological College, I have found certain specimens and phenomena that are very interesting and important from the point of view of palaeobiology, as well as of that of palaeogeography. In the following pages the results of these observations will be briefly described.

II. The city of Tainan stands on the western, i. e., windward slope of an old coastal sand dune, stretching in a N–S direction. The surface of the dune hill is covered by a thin layer of loose sand which, no doubt, is of eolian origin, about 2 m. in thickness or possibly less within the grounds of the Higher Technological College. A pit about 4 or 5 m. deep had been dug there for a certain purpose, and a fossiliferous bed just below the surface sand layer was exposed on the wall of the pit. It is a blue-gray, fine, sandy shale about 2 m. thick, sandstone following below. The fossil shells are all small in size, the most attractive feature of the bed being the abundance of *Turritella* cfr. *terebra* L. Larger shells of *Chama semipurpurata*, *Ostrea Laperousei*, *etc.* are also not infrequent,

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VI, No. 4, July, 1933].

but they are much smaller than usual. Of the pelecypods in this faunule, the most common is perhaps the "*Chione marica*" PILSBRY, which, according to KURODA, is nothing but a young stage of *Anomalocardia squamosa* (LINNE), which, in Taiwan, is found in abundance in the coastal sandy and clayey beds.

The loose sandy shale was washed with running water, and many minute molluscan shells were sieved out of it together with several species of the smaller foraminifers of the MILIOLIDAE and ROTALIIDAE, as well as a species of *Cythere*.

These constitute the main material upon which the present paper is based. The discussion is further supplemented by observations made on some other young Tertiary molluscs from other parts of Taiwan.

III. Concerning the boring activities of *Natica* and similar mussel borers a number of observations and a few experimental studies have been made by several zoologists. Some time ago BOETTGER of Berlin published a paper in which he summarized the experimental observations carried out by himself a few years ago in the Marine Laboratory of Naples.(1) He made careful observations on the activities, in the aquarium, of certain species of *Natica* that are very commonly found in the neighbourhood of Naples. These gastropods live buried in the sand, at a depth of about 2–5 cm., where they find their prey. His attention was particularly directed to the position of the bore-holes on the attacked mussel shells. From his interesting and very valuable paper, we can gather the most important and interesting points concerning the problem of the boring activities of the gastropods in general.

According to his observations, when the sand layer in which both the gastropods and the pelecypods live is not less than 10 cm. thick and the number of the gastropods is small, the bore-hole is usually in the neighbourhood of the beak. The more numerous the gastropods in a limited space, the more irregular the position of the bore-hole on the mussel valve. As the sand layer becomes thinner, the position of the bore-hole becomes irregular, and this irregularity, in the case of *Natica millepunctata* LAM. and *N. hebraea* MART., reaches its maximum when the sand layer is 7.5 cm. Naturally, the relative position of the gastropod and of the prey also affects the position of the hole.

---

(1) BOETTGER, C. R.:—Die Lage der Bohrstelle beim Angriff der Raubschnecken aus der Familie Naticidae. Zeitschr. f. wissenschaftl. Zoologie, Bd. 136, pp. 453-463, 1930.

The question of the position of the bore-hole on the pelecypod shells seems to have been solved by BOETTGER's observations. In nature irregularity in the position of the bore hole is to be expected just as it is in other phenomena of various kinds. In the bored specimens of "*Chione marica*" PILSBRY occurred in Tainan, this irregularity is very obvious (Fig. 1, Pl. I [XVIII]). The variation of the relative size of the mussel attacked and the gastropod has also some bearing upon the position of the hole. When the gastropod is relatively large by comparison with its prey, the bore-hole shifts to the back of the beak, and *vice versa*.

As to the position of the bore-hole on the valve, we have evidence of irregularity both from the zoological and the palaeontological sides. Another question that arises, concerns the valve--whether right or left—on which the hole is bored. It is said that P. SCHIEMENZ found, among his 79 bored specimens, 28 right valves and 49 left ones, the other 2 being bored at the shell margin. The apparently valid explanation offered that, owing to the invariable winding direction of gastropods, the left valves of the attacked pelecypods are bored, is rejected however by BOETTGER, who is of the opinion that this is merely accidental. My material also seems to prove BOETTGER's theory. Fig. 1, Pl. I (XVIII) again offers evidence in its support.

The third point to be considered is, whether the boring activity is chemical or mechanical or, possibly, both. BOETTGER says that he had not enough time to make observations on this point. According to him, P. SCHIEMENZ considered the boring work to be chemical in NATICIDAE, while various authors including K. LOPPENS (1927), regarded the work in general to be mechanical. BOETTGER himself seems to be of the opinion that, at least in the NATICIDAE it is caused by a chemical process due to secretions from certain glands. HANS KLÄHN in discussing this problem in his recent paper, seems to consider the main factor in the boring action as due to the "physiologische Schwefelsäure" secreted by the stomach.(1)

In my material there are several specimens in which the bore-holes are not completely circular but are very irregular in outline, the irregularity being due to the differential resistance of the sections of the shell,—the shells being much thicker on the radial ribs than in the intercostal furrows. Thus, the process of chemical solution penetrates the thinner part of the shell much more quickly than the thicker. The figures on Plates II [XIX] and III [XX] are given to show various stages of the development of the bore-hole. As far as my observations are concerned, there is hardly any trace of mechanical work in the boring, although it may be conjectured that the first step in the boring work may have been mechanical, *i. e.* the grinding down a part of the shell surface to prepare it for an effective commencement of the chemical work.

Finally, it is very interesting to note that there are a few specimens of shells that have two holes bored, as is shown in Figure 2 (lower row), Plate I [XVIII].

IV. Among the very minute molluscan shells that were sieved out from the sandy shale, there were a number of pelecypod valves that are bored. The shells average about 1 mm. across, and some of them are even 0.6 mm. The holes bored by gastropods have a characteristic, conical shape, the diameter of the circular opening outside and inside the shell being rather markedly different. This characteristic is very clearly observed in my minute shells (Pl. IV [XXI]).

In association with these minute pelecypods there are, of course, numerous minute gastropods, many of which have protoconchs in an excellent state of preservation. Among them, no doubt, are the borers, although it is not easy to determine which they may be.

I found it very interesting to observe that, even at such an early stage of life as these minute shells are, the struggle for existence can not be avoided in nature.

---

(1) KLÄHN, HANS:—Der Bohrakt fossiler Bohrender Schnecken und das Vernichtungsmass durch räuberische Gastropoden des Sternberger Oligocän. Sitzungs-Ber. u. Abhandl. Naturf. Gesellschaft Rostock, 3. Folge, 3, p. 89–103 (1932). Not accessible but a review is found in N. Jahrb. f. Min. etc., III, p. 921 (1932).

V. Sometime ago, I had an opportunity to examine the mode of occurrence of molluscan fossils in a young Tertiary sandy shale exposed near the village of Hakusyaton, Shintiku Prefecture, Taiwan. Among the many species, there are abundant specimens of "*Venericardia cipangoana* Yok.,(1) many of which are bored shells. It is worth mentioning the fact that these bored shells are very often in pairs, that is, right and left valves attached in the natural position, lying with the bored valves on the top. Although we have no knowledge concerning the borer, there is the possibility that these pelecypods were attacked in a way different from that described by BOETTGER.

VI. In connection with the problem of the bore-hole of pelecypods, I may mention, among the minute sieved-out specimens of molluscs, the occurrence of a single specimen of a minute gastropod most probably of the NATICIDAE, which has a small hole of rather an irregular outline. The shell itself is roughly about 1 mm. across. The hole is at a little distance from the mouth. This may be considered as an example of the cases recently discussed by EHRENBERG,(2) to the effect that gastropod shells that were occupied by hermit-crabs are mechanically worn out at the point of contact with the ground. As the hermit-crabs creep around the gastropod shells touch the ground at one and the same point, so that the shells come finally to be worn through. The specimen under discussion may be regarded, if my interpretation of the hole in my specimen is not mistaken, as suggesting the existence of very minute hermit-crabs.

VII. The sandy shale of Tainan which yielded the fossils discussed above is very fine-grained, and of a somewhat bituminous nature. Fossils are very well preserved, and even the very fragile parts of specimens of either molluscs or forminifers are found undisturbed. It seems that the bed was deposited where the sea was calm, somewhat as in an estuary, protected from waves and winds by off-shore bars, sand spits or the like. As is known, many marine molluscs grow to a certain early stage in such conditions as these, whence they subsequently disperse to their final abode. The small and markedly uniform sizes of the respective kinds seem to conform to this habit of molluscan life.

---

(1) According to Mr. KURODA, this species is identical with *Venericardia ferruginosa* (AD. & RVE), which was originally described as *Cardita ferruginosa* in "Zoology of the Voyage on H. M. S. Samarang; under the Command of Captain Sir EDWARD BELCHER, C. B., F. R. A. S., F. G. S., during the years 1843-1846," p. 76. pl. xxi, fig. 21, 1850. The original material was from the "Philippine Archipelago." See also KURODA:—"Gastropoda and Lamellibranchiata" in IWANAMI's Manual of Geology and Geography, 1933.

(2) EHRENBERG, K.:—Ueber Lebensspuren von Einsiedlerkrebsen. Palaeobiologica. IV, p. 137-174 (1931).

VIII. Conchologists often overlook such minute specimens as I have discussed in this paper. It is very interesting to find that the phenomena of life in such an early stage of development are preserved in the rock. By seeking for similar specimens on the present-day shore zones, our knowledge concerning molluscan life would be increased.

The scientific mind looks for a law, or laws, but it often overlooks the law of lawlessness, or irregularity, that is rather common in Nature. The position of the hole on the pelecypod shells is no doubt a case of lawlessness, or irregularity, in palaeontology. Although we do not know the details of the boring activities of gastropods of prey, the chemical method they have used is distinctly recorded on the prey.

In conclusion, I want to offer may hearty thanks to Mr. WAKATSUKI, Director of the Tainan Technological College, by whose kind help I have been enabled to bring back a good quantity of the fossiliferous sandy clay to my laboratory. To Mr. KURODA, of the Kyôto Imperial University, I owe the specific determination of "*Chione marica*" (PILSBRY) as well as the information concerning the systematic position of what has been called "*Venericardia cipangoana* YOKOYAMA," for which I am duly grateful to him.

(May 10, 1933)

PLATE I [XVIII].

Explanation of Plate I [XVIII].

(All figures, natural size)

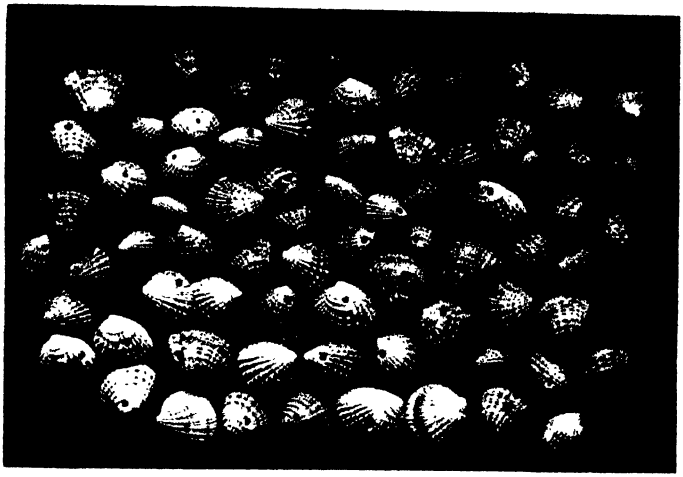
Fig. 1. "*Chione marica*" (PILSBRY). Specimens with bore holes, selected from among the many specimens collected. The irregularity in the position of the hole on the shell is recognized at once. It should also be observed that there are both right and left valves. I do not try to give the percentage, because the number of the specimens is not sufficient for that.

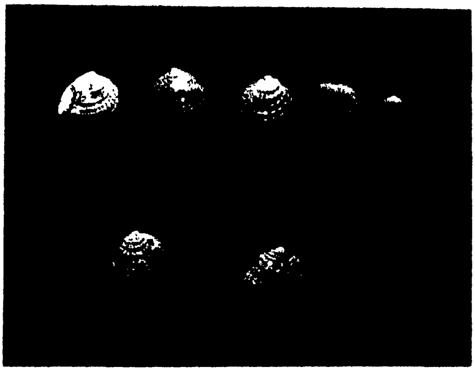
Fig. 2. "*Chione marica*" (PILSBRY). The five specimens above are given to show various stages in the development of the hole. The holes of these are strongly magnified on Plates II [XIX] and III [XX]. Counting from the left, No. 1 corresponds to Fig. 1, Pl. II [XIX], No. 2, to Figs. 2 and 3, No. 3, to Fig. 1, Pl. III [XX] and No. 4, to Fig. 2, Pl. III [XX].

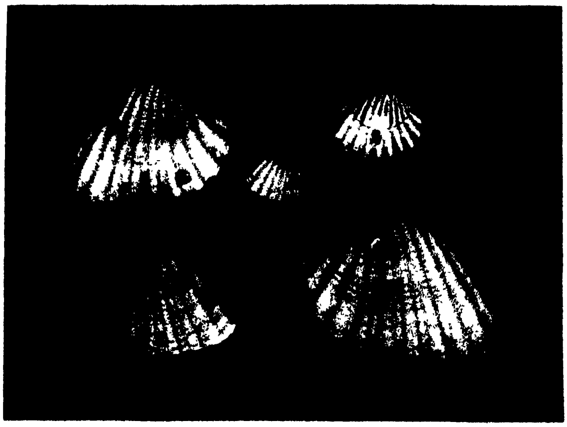
The two specimens below have two holes: in the left specimen, holes are on front and back of the beak, while in the other, one hole is near the middle and the other is close to the anteroventral margin.

Fig. 3. "*Venericardia cipangoana* YOKOYAMA." Specimens with bore-holes, selected from the material from Shintiku Prefecture. Note that there are both right and left valves, as well as that there is no rule with regard to the position of the hole.

I. HAYASAKA: *Fossil Occurrence of Pelecypod Shells.* Plate I [XVIII].







Hayasaka photo.

PLATE II [XIX].

Explanation of Plate II [XIX].

Figs. 1–3. Magnifications of the bore holes of "*Chione marica*" (PILSBRY). × 30. Fig. 1 is the magnification of specimen No. 1 (from the left), Fig. 2 (upper), Plate I [XVIII]. This stage is earlier than the one represented by Fig. 2, which is a partial magnification of specimen No. 2 (from the left), Fig. 2 (upper), Plate II [XIX]. The rib part of the shell still remains.

Fig. 3 shows the inner side of Fig. 2.

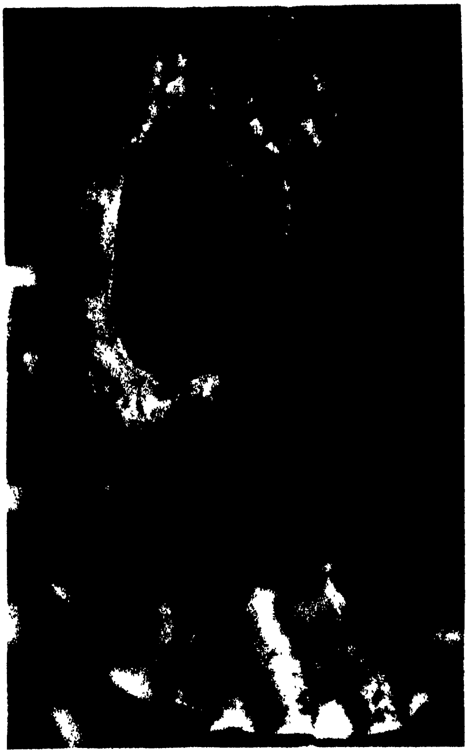
Hayasaka photo.

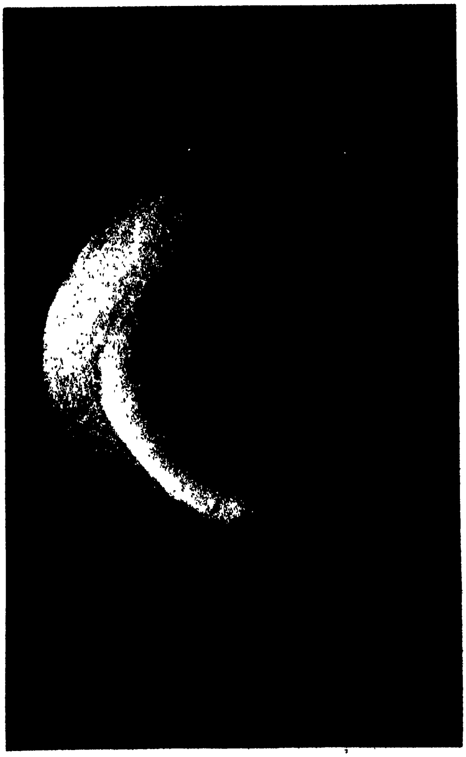
PLATE III [XX].

Explanation of Plate III [XX].

Figs. 1–3. "*Chione marica*" (Pilsbry). ×30. Fig. 1 corresponds to specimen No. 3 (from the left), and Fig. 2, to specimen No. 4, both in the upper row, of Fig. 2, Plate I [XVIII]. The stage of boring represented by Fig. 2, Plate II [XIX] may be followed by the one represented by Fig. 2 and then by the other represented by Fig. 1. In Fig. 3 the hole has become single, though the outline is not circular as in the typical cases.

Fig. 4. *Tellina* sp. This figure is given to show that (1) the hole is on the margin, and (2) the hole finally becomes circular in outline. In ribbed forms like "*Chione marica*" a typically rounded hole seems to be rather exceptional.





Hayasaka photo.

PLATE IV [XXI].

Explanation of Plate IV [XXI].

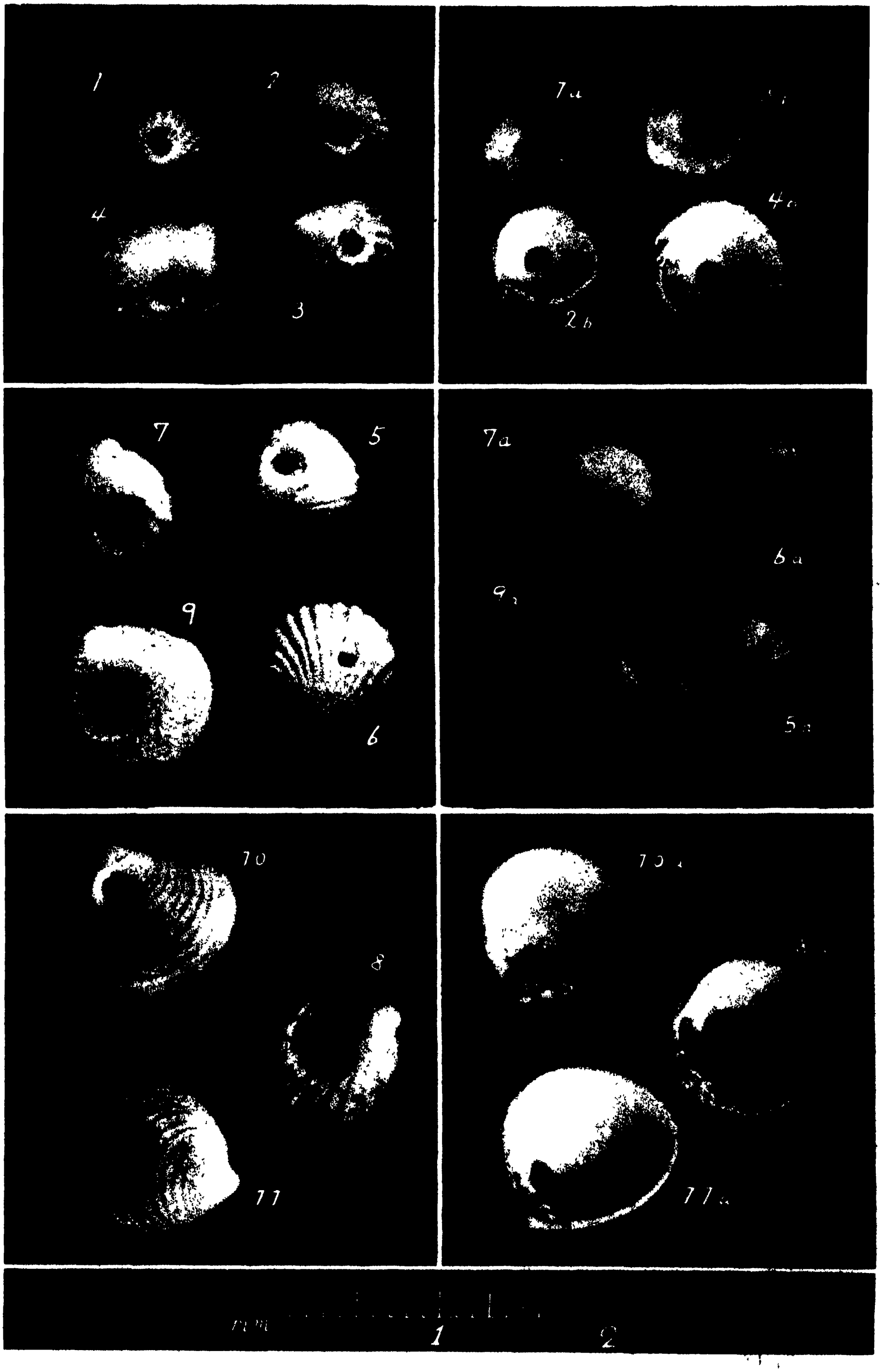
Figs. 1–8, 1a–8a. *Venericardia* sp. × ca. 23.

Figs. 9–11, 9a–11a. *Pitaria* sp. × ca. 23.

All the figures are given to show (1) that such minute and early specimens like these had fallen prey to gastropods, (2) that the position of the hole is not definite, and that both right and left valves are found among bored specimens.

Admitting that the generic determination is correct, it is difficult to decide to what species these minute specimens really belong.

I. HAYASAKA: *Fossil Occurrence of Pelecypod Shells.* Plate IV [XXI].



Hayasaka photo.

GEOLOGICAL NOTES ON THE MOZAN IRON-BEARING DISTRICT, N. KANKYÔ-DÔ, CHÔSEN (KOREA).

By

Takeshi ICHIMURA.

(With 4 Text-Figures and Plates I.IV [XXII-XXV]).

(Accepted for publication, July 10th, 1933)

CONTENTS.

Introduction. 72

Topographic Feature. 72

Geology. 73

Sedimentaries. 74

The Distribution of the Ferruginous Rocks. 74

The Metamorphosed Sediments Associated with the Ferruginous Rocks 76

Quaternary Sediments. 78

Intrusives and Extrusives. 78

Schistose Granite and Augen-gneiss. 78

Amphibolite. 81

Hornblende-biotite-quartz-diorite. 82

Diorite-porphyrite and Lamprophyre.... 83

Basalts. 86

The History of Igneous Activities. 88

A Treatise on the Tectonic Disturbance. 91

Characters of Haematite-magnetite-quartzite and Haematite-magnetite-quartz-schist. 92

Genesis of Haematite-magnetite-quartzite and Haematite-magnetite-quartz-schist. 96

Possibility of Enriched Ore Bodies. 99

Sources of Iron. 100

Summary. 102

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol, VI, No. 5, August, 1933].

INTRODUCTION.

The occurrence of the so-called banded iron ores is known in several regions of Korea where various kinds of metamorphics are extensively exposed. They are mostly associated with quartzite, mica-schist, paragneiss, etc. identified by S. Kawasaki and others with the Pre-Cambrian or Cambrian. These metamorphics are intruded by schistose granite, diorite, diorite-porphyrite, etc. It is noteworthy that such banded iron ores are somewhat similar in character to those of the Lake Superior regions. They are always highly quartzose, being sometimes intercalated by enriched ore bodies.

The largest exposure is found at the northern terminal of Mozan-gun, N. Kankyô-dô, where it is exposed in the vicinity of a small frontier town called Mozan (茂山 Fig. 3, Pl. I 〔XXII〕) which is about 80 Kilometers southwestward from Kainei and about 60 Kilometers westward from Komozan (古茂山). It is now easily approached from Komozan, passing through Shayurei (車踰嶺) and Hôzan-dô (豐山洞).

The so-called banded iron ores there are mostly composed of very poor ores, viz., haematite-magnetite-quartzite or haematite-magnetite-quartz-schist, which can not be utilized without magnetic concentration. However, an enormous amount of such ores is considered to be an important source of iron in future. It is owned by the Mitsubishi Iron and Steel Works, but hitherto no mining operations have been conducted.

The writer was there in field work for several weeks. An outline of this has already been described in his preliminary note, and the present paper is a farther extension of the geological investigation of this iron-bearing district.

For this, the writer is deeply indebted to the Mitsubishi Iron and Steel Works.

TOPOGRAPHIC FEATURE.

The area surrounding this iron formation is mostly mountainous, and often rises up to 1,000 meters or more above the sea level. It is deeply dissected and highly cliffed particularly along the Tôman-kö (豆

滿江) and Jôsen-sui (城川水), showing now the climax of the maturity (Figs. 2 and 3, Pl. I [XXII]). The topographic feature here is much influenced by the presence of various structural lines parallel to the present river course of the Tôman-kô. The iron formation sometimes prominently projects out from others, forming many rugged peaks which are more than 1,000 meters at the highest point. It is thickly forested with brushwood.

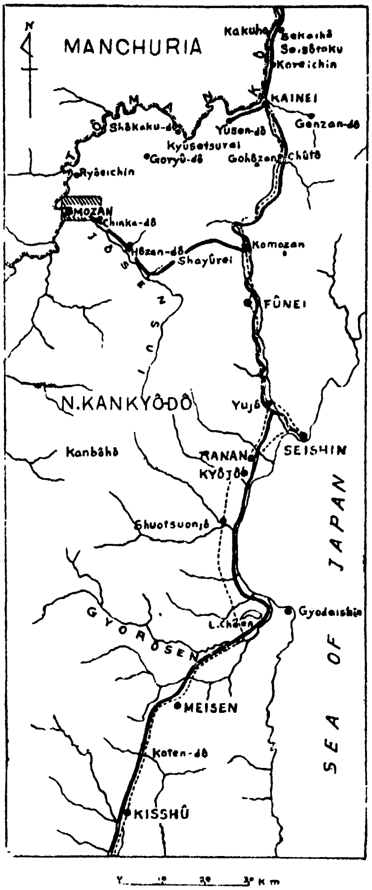


Fig. 1.

Index map of a part of N. Kankyô-dô including the Mozan Iron-bearing district.

GEOLOGY.

The mountainous area under consideration is mainly made up of various kinds of metamorphics as well as many intrusives and extrusives. Among them the most predominant are schistose granites which were intruded into the oldest formation intercalating the ferruginous rocks. The small but frequent intrusions of quartz-diorite and such hypabyssal rocks as lamprophyre or diorite-porphyrite took place in a later age. Basalt lavas here were undoubtedly erupted in the Quaternary period. Even the oldest one is underlain by a loose gravel bed which is accumulated on the old river bed of the Tôman-kô.

Various field evidences indicate that there were several disturbances or diastrophisms. They are particularly obvious in the displacement of the iron formation and associating sedimentaries. Quartz-diorite and hypabyssal rocks are similarly displaced by these faults. Furthermore, the present river course of the superimposed Tôman-kô seems also to be influenced by them. The most remarkable one corresponds to the disturbance which is partly shown by the presence of very characteristic fault lines called the Kankyô System, predominant in the Meisen-Kisshû (明川—吉州) and Kainei-Keigen (會寧—慶源) districts. The extrusion of basalt lavas here is, however, later than such a diastrophism.

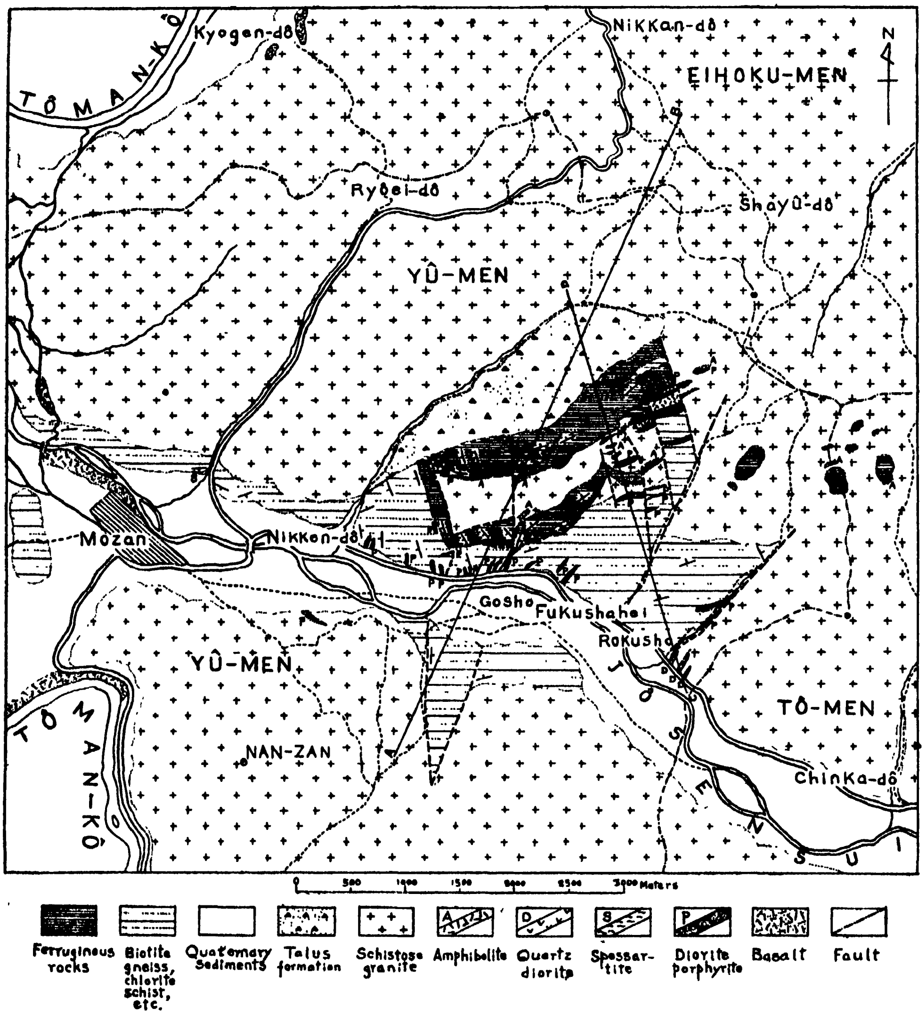


Fig. 2.

Geological map of the Mozan iron-bearing district.

SEDIMENTARIES.

The distribution of ferruginous rocks :—The ferruginous rocks are extensively exposed in the steeply mountainous area near the northeastern corner of Yû-men (邑面). They are found here in association with various kinds of metamorphics and intrusives, often showing a very complicated geologic structure. These ferruginous rocks begin to be exposed in the vicinity of Nikken-dô and are traceable about four kilometers northwestward across the boundary beween Yû-men and Tô-men (東面). However, their downward extension is much decreased in the eastern area where they are separated into many fragmental masses resting upon red schistose granite. They are likely to be preserved on the top of the ridge. These detached exposures are often distinctly bedded and highly inclined northwestward, while some of them are only composed of crumbled blocks scattered over the slope. Such erosion remnants can be seen on several ridges extending southward between Chinka-dô (珍貨洞) and Fukushahei (福沙坪).

These rocks are more complicately exposed in the western area where it has particularly been subjected to severe disturbances; There are two prominent zones, meeting together at the eastern end; one of them is found along the summit of the ridge with a northeastern trend, whereas the other traverses its southern slope in close association with the former (Figs. 1, 2 and 3, Pl. I [XXII]). These zones extend about 2.5 kilometers, and are sometimes penetrated by red schistose granite, diorite-porphyrite, amphibolite, etc. They are mostly built up of fault blocks and indicate such various inclinations as 70°–80° NNW, 60°–80° WSW, etc.

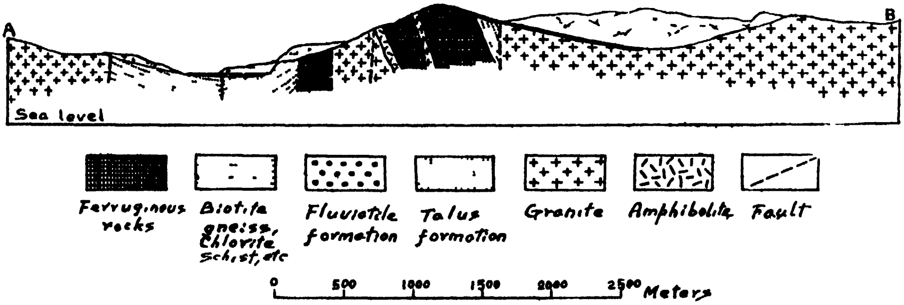


Fig. 3.

Section of a part of the Mozan iron bearing district.

The northern zone is thickly covered by talus deposits along the valley of Nikken-dô, and it is bordered by a red schistose granite in the opposite side. The thickness of the outcrops here varies much from place to place. The maximum thickness is estimated to be 500 meters, but the total thickness including the invisible part is probably much greater. On the other hand, the southern zone is in contact with biotite-gneiss or red schistose granite. Its outcrop shows a tendency to diminish its thickness both eastward and westward. It is thinner than that of the northern zone, and the thickness does not exceed 250 meters.

Furthermore, there are some subordinate patches in the eastern terminal of these zones. They are frequently displaced by faults and are not extensively exposed.

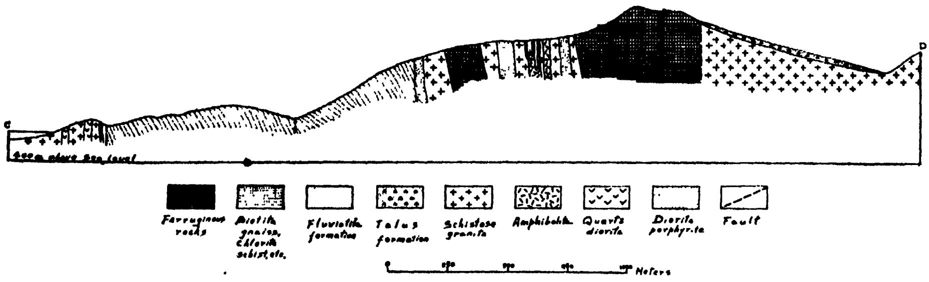


Fig. 4.

Section of a part of the Mozan iron-bearing district.

The metamorphosed sediments associated with ferruginous rocks:—There is an isolated exposure of extremely metamorphosed sediments along the lowest course of the Jôsen-sui. It is traceable for about 9 kilometers in length and is 3 kilometers in its broadest part. These metamorphics are mainly composed of biotite-gneiss, epidote-biotite-gneiss, hornblende-biotite-gneiss and biotite-schist resting upon the schistose granite. They are highly disturbed by many faults, showing various strikes of sheared plane, such as N30°–45°W at Fukushahei or Rokusho (六所), E-W to N85°E at Gosho (五所), N-S at Nikken-dô (日建洞), E-W to N85°W in the vicinity of Mozan. The rocks are generally finely banded with the alternation of biotite or quartz-feldspar-rich parts, but some of them are almost free of ferromagnesian minerals. In such a case they are somewhat similar to schistose granite. At sometime or other these gneisses are likely to pass into chlorite-shist.

The constituent minerals of these rocks are quartz, biotite, orthoclase, plagioclase, hornblende, chlorite, apatite, epidote, allanite, pyrite, magnetite, calcite, etc. (Fig. I, Pl. II [XXIII]).

The most dominant constituent in all specimens is quartz which occurs in a mozaic or interdented aggregate. The large grain is often changed to a very fine aggregate of particles, yielding the so-called mortal structure. An undulately extinction is very remarkable in this case. Anhedral plagioclase and flaky biotite are also important minerals of these rocks. The common variety of plagioclase is basic oligoclase ($Ab_{68}An_{32}$), the largest crystal being 1.2 mm. × 0.85 mm. in size. The indices of refraction are $n_1=1.544$ and $n_2=1.548$ on (010). It twins after the albite law with a somewhat twisted twinning lamellae due to shearing. The mineral is frequently sericitized. Albite is less abundant. Biotite (Nm=1.628) is found in a confused aggregate generally together with epidote. It is partly chloritized. The occurrence of epidote is particularly noticeable in the specimens collected from the cliff between Fukushahei and Nikken-dô. This mineral mostly takes a granular form and sometimes the crystal is characterized by a perfect cleavage parallel with (001). It is slightly pleochroic from colourless to light yellow, and shows a bright interference colour. However, some of it may be zoisite, as it gives a very low interference colour. Epidote crystal not infrequently passes into allanite at its core, both minerals being sharply bordered. Allanite is also pleochroic, viz., X=yellowish brown, Y=brown, Z=dark brown. The absorption of this mineral is $Z>Y>X$. Apatite appears in a granular or stout primatic form. It is very commonly observed in the specimens from Nikken-dô and Rokusho. The largest crystal is 0.3 mm. in diameter. Granular magnetite and cubic or granular pyrite are associated with biotite. Calcite is a secondary mineral derived from plagioclase in weathering.

The writer has also observed other exposures of metamorphosed sedimentary rocks in this region. One of them is exposed along the upper course of Jôsen-sui between Hinshi-dô (賓主洞) and Shôtoku-dô (小篤洞). It is intruded by schistose granite and augen-gneiss. In general, the rocks here are less metamorphosed. The presence of chiastolite crystals in black clay slate is an evidence of contact metamorphism due to the granitic intrusion. An isolated exposure found along the valley of Goryû-dô (五龍洞), about 20 kilometers northeast from Mozan, extends from northeast to southwest. It is traceable for about 8 kilometers. This formation is composed of hornfels, schistose conglomerate, mica-schist, quartzite, limestone, etc. A haematite-magnetite- schist of 6 meters or thereabouts in thickness, is exposed in its uppermost horizon together with diorite. There is also clear evidence of contact metamorphism.

In the present condition, it is quite impossible to find out their geological correlation, but the isolated metamorphics in the vicinity of Mozan is undoubtedly older than schistose granite. Some of them are quite similar to the Hekijô formation (Permo-Carboniferous?) in the Kainei district.

Quaternary sediments :—Quaternary sediments are chiefly found along the Jôsen-sui and Tôman-kô. Some of them are preserved on the old river terrace. There is an erosion remnant of such old gravel beds at the northern side of the Jôsen-sui near Mozan. It is exposed on the cliff 15–90 meters above the present river bed and is composed of loose gravel and sand which were mainly derived from paragneiss, ferruginous quartzite, schistose granite and basalt. The petrographical character of this basalt is quite similar to those of the oldest lavas preserved on the terraces near Kainei. The gravel bed mentioned above is covered by titaniferous augite-olivine-basalt.

INTRUSIVES AND EXTRUSIVES.

Schistose granite and augen-gneiss :—The most remarkable geological feature of this region is the predominant occurrence of schistose granite. It is sometimes exposed in association with metamorphosed sedimentaries which are now isolated erosion remnants. There are several textural or mineralogical varieties, such as red schistose granite, schistose biotite- granite, schistose hornblende-biotite-granite, augen-gneiss, etc.

(i) Among them red schistose granite is to be found in an extensive area, including Yû-men (邑面), Eihoku-men (永北面), and Tô-men (東面). The paragneiss as well as ferruginous rocks here rest upon this enormous intrusive mass. Some lenticular exposures or irregular dykes of schistose granite are often found in the iron formation. It is also very complicately injected between metamorphosed sediments, as shown at Nikken-dô, forming a coarse banded structure with alternate arrangement of them.

Red schistose granite is a fresh-coloured rock with a gneissic structure. The grain size of this rock varies and it is usually composed of quartz and feldspars with a small amount of ferro-magnesian minerals. However, it gradually increases the amount of such coloured minerals in the transition stage to other varieties.

The red schistose granite is composed of quartz, microcline, orthoclase, perthite, albite, andesine, apatite, biotite, epidote, allanite, pyrite, zircon, titanite, sericite, chlorite, limonite, calcite, etc. (Fig. 2, Pl. II [XXIII]).

Quartz grains are abundantly present in mozaic or interdented aggregates with a mortal structure. In each grain they show a conspicuously undulatory extinction. Microcline is also a common mineral in the specimens from Rokusho as well as from Nikken-dô. It occurs as anhedral phenocryst which is 3 mm. in the maximum diameter, being often crushed and twisted. Certain tendencies show that this mineral partly passes into perthite. Orthoclase and andesine are not so abundant, and some of them are remarkably sericitized. The largest andesine crystal is 2 mm. or thereabouts in diameter. The Indices of refraction are $n_1=1.551$ and $n_2=1.557$ on (001). It twins after the albite law and twinning lamellae are very frequently bent. The amount of orthoclase and plagioclase is nearly equal in the red schistose granite from the valley between Fukushahei and Rokusho. The occurrence of albite is, on the other hand, rare. A minor amount of biotite and epidote is seen in almost all thin sections. In some specimens, such as those from Rokusho or elsewhere, titanite crystals are observed. This mineral is always anhedral, and slightly pleochroic, with a small 2V. It is 0.8 mm. in maximum diameter. Besides these, there is a very small amount of apatite, zircon, allanite, limonite, and calcite.

(ii) Schistose biotite-granite is well exposed at Nanzan-dô (南山洞) or somewhere near Shayû-dô (車踰洞). It sometimes passes into the hornblende-biotite-bearing varieties. The rocks mostly have a coarse granular texture and are of gray colour, but constituent minerals are almost similar to those of red schistose granite excluding the presence of abundant biotite and the frequent occurrence of hornblende.

(iii) Augen-gneiss is a schistose modification of porphyritic granite with abundant eye-shaped orthoclase. A characteristic transition stage can be seen at Hinshi-dô, also at other places where the phenoblastic orthoclase is gradually deformed and is finally flattened to a lenticular form. It consists of quartz, orthoclase, plagioclase, biotite, hornblende, titanite, apatite, magnetite, pyrite, zircon, etc.

Orthoclase is more abundant than andesine which is characterized by albite or pericline twins. The characteristic feature of this rock is the abundance of biotite and hornblende. Biotite is confusedly scattered as minute flakes, being partly chloritized. Hornblende is strongly pleochroic, viz., $X=$yellow, $X=$yellowish green, $Z=$bluish green, $Z>Y>X$. The extinction angle, $c\wedge Z$, is 17°. Quartz grains fill up the interstices of these minerals. Titanite is also a noticeable mineral, occurring usually in a granular form. It is slightly pleochroic with a very high birefringence. Apatite, magnetite, pyrite and zircon are present in small amounts.

The schistose granite of this region may be a local facies of enormous granitic masses. Although there are various modifications, they are mostly differentiated products from the same magma. It seems highly probable from field evidences that the red schistose granite is generally predominant along the contact with the paragneiss or ferruginous rocks, passing gradually into schistore biotite or hornblende-biotite-granite or sometimes augen-gneiss. They are hitherto summarized, in the general geological map of Chôsen, as a gray granite-gneiss belonging to the Pre-Cambrian.

Amphibolite: - There are many exposures of amphibolite in association with the schistose granite and iron formation, particularly along the contact between them. The rock is found as a sheet or dyke arranged nearly parallel with the extension of the iron formation, and it is remarkably exposed in the uppermost course of the valley between Rokusho and Fukushahei. The amphibolite here is a somewhat schistose rock with a dark green colour. The constituent minerals of this rock are mainly plagioclase and hornblende. There is also the frequent occurrence of titaniferous magnetite, epidote, and chlorite (Fig. 3, Pl. II [XXIII]).

Plagioclase belongs to albite with the following indices of refraction on (001), viz., $n_1=1.529$, $n_2=1.539$. It shows a polygonal or very irregular form, filling up the interstices of a confused aggregate of hornblende crystals and twinning after a carlsbad law or rarely pericline law. The size of the crystals range from 0.08 mm. to 1 mm. in diameter. In some specimens it is conspicuously sericitized.

Anhedral hornblende occurs in almost the same amount as albite. It is strongly pleochroic, viz., X=yellow, Y=yellowish green, Z=bluish green with a yellowish shade. The absorption is $X<Y<Z$. However, it gradually gets a light bluish colour and fine fibrous texture in the alteration stage to chlorite. In such a case irregular cores of unaltered hornblende still exist here and there. The inclosure is titaniferous magnetite which is granular in its form. Most magnetite is associated with titanite and leucoxene. The amount of these minerals is not abundant. Apatite is rare. Epidote is a very common secondary mineral in all thin sections where they are occasionally traversed by its veinlets. The crystal is always granular, usually showing a characteristic pleochroism, viz., X=colourless, Y=yellow, Z=colourless. The cleavage parallel with (001) is distinctly observed. Chlorite is derived from hornblende, and it is frequently in close association with epidote.

Amphibolite is mostly in a sharp contact with intruded rock without any remarkable textural variation. As its mode of occurrence shows, it may be a metamorphosed product from some basic intrusives injected soon after the enormous granitic intrusion.

Hornblende-biotite-quartz-diorite:—The schistose granite is intruded by quartz-diorite at Rokusho near the boundary between Yû-men and Tô-men. There are five dykes, 7 meters to 50 meters, traversing the cliff along the road. It is a hard and compact rock with a dark gray or black colour and medium or fine-grained texture from the inner part to the contact of these dykes.

The constituent minerals are quartz, plagioclase, hornblende, biotite, augite, apatite, magnetite, chlorite, epidote, calcite, sericite, etc. (Fig 4, Pl. II [XXIII]).

Quartz is an accessory constituent with a granular form, filling up the interstices of plagioclase or other minerals. The plagioclase crystal is anhedral or subhedral and it is 3.4 mm. x 0.8 mm. in maximum size. It twins after albite or carlsbad or pericline laws. In some crystals the zonal structure can be seen, the core being usually more basic than the margin. The Indices of refraction are measured as follows; $n_1=1.532$–1.548, $n_2=1.541$–1.555 on (001). Hence this plagioclase ranges between albite and andesine ($Ab_{91}An_9-Ab_{59}An_{41}$). The crystal is partly replaced by sericite or calcite. Biotite is a main constituent, partly changing to chlorite along its cleavage. The index of refraction is $N_m=1.627$. It is often associated with hornblende and includes magnetite, epidote, and apatite. Hornblende is not so abundantly present as biotite. This mineral is always anhedral and is distinctly pleochroic: X=light yellow, Y=yellowish green, Z=bluish green, or X=light brown, Y=yellowish brown, Z=dark yellowish brown. The absorption is $Z>Y>X$. The basal section is observed in the thin section. Augite is mostly surrounded by hornblende, both minerals being sharply and irregularly bordered. The cleavage parallel with (110) is well observed and it shows a large extinction angle, viz., $c\wedge Z=38°$. The inclosures are apatite and magnetite. Apatite is a very common mineral in this rock. Its crystal is anhedral or subhedral and occurs in a prismatic or acicular or granular form. The largest crystal is 1 mm. in length. Some apatite crystals are hollow or skeletal. A six-sided basal section is frequently observed. Magnetite is associated with biotite, pyrite, and hornblende. It is abundantly found in a granular or skeletal or octahedral form with the narrow rim of titanite. The largest diameter is 0.5 mm. Pyrite is rare. Chlorite, calcite, epidote, and sericite are secondary minerals.

As will be understood from the above description, it is evident that apatite and magnetite were formed in the earliest stage of crystallization. They were followed by augite, hornblende, biotite, andesine, and quartz in order.

The intrusion of quartz-diorite here is obviously later than that of schistose granite. It has many similar points to those of Goryû-dô and Hôseki-dô (豐石洞) of Hôkei-men (豐溪面).

Diorite-porphyrite and lamprophyre:—The geologic feature of the area under consideration is much complicated by the frequency of hypabyssal rocks. These rocks are found as a sill or dyke injected into the metamorphosed sedimentaries and schistose granite. Some of them are exposed along the contact between schistose granite and iron formation. They are diorite-porphyrite and lamprophyre.

(i) Diorite-porphyrite :—Many exposures of diorite-porphyrite can be seen in the vicinity of the iron formation or in association with it. It is a porphyritic and compact rock with varying colours from dark gray to dark greenish gray or gray. There are two varieties, that is, biotite-diorite-porphyrite and biotite-hornblende-diorite-porphyrite. The mineral constituents of these rocks consist of plagioclase, biotite, hornblende, magnetite, titanite, apatite, quartz, sericite, epidote, chlorite, calcite, tremolite, etc. (Fig. 1, Pl. III [XXIV]). Among them plagioclase, hornblende, and biotite occur as phenocryst as well as in the groundmass.

The crystal form of plagioclase is tabular or lath-shaped, and it is often euhedral in phenocryst. The phenocryst is usually well zoned and sometimes shows a turbid appearance. Such zones are repeatedly arranged without any regular decrease of basisity outwards. Furthermore, perthitic intergrowth is rarely observed. The largest phenocryst is 1 cm. in diameter. Albite or carlsbad twins are very distinctly seen. The indices of refraction on (010) are $n_1=1.543-1.555$ and $n_2=1.550-1.561$. Hence it ranges from acidic andesine to acidic labradorite ($Ab_{70}An_{30}-Ab_{49}An_{51}$). The plagioclase of the groundmass is also anhedral or subhedral, being arranged in a confused aggregate together with biotite, hornblende, magnetite, quartz, etc. It frequently forms a granophyric or micropegmatitic texture, as is shown in the case of biotite-diorite-porphyrite from Nikken-dô. Such textures are mostly found around the phenocrystic plagioclase. The size of the lath-shaped crystals is very variable, but the longer diameter is generally 0.03 mm.–0.17 mm. The indices of refraction on (001) are as follows: $n_1=1.537$, $n_2=1.545$. This plagioclase is, therefore, oligoclase ($Ab_{82}An_{18}$). In all thin sections it is partly altered to sericite.

Hornblende is absent or very rare in biotite-diorite-porphyrite, but it is abundantly present in other varieties, as a phenocryst or minute crystal in the groundmass. The crystal indicates stout or long prismatic habits, occurring in anhedral or subhedral forms which often twin on (100). The indices of refraction are measured as follows: $n_1=1.652$ and $n_2=1.665$ on (110). A six-sided basal section is sometimes seen. It is distinctly pleochroic: X=light yellow, Y=brownish green, Z=bluish green. The absorption is $Z>Y>X$. The extinction angle, $c\wedge Z$, is 15° or thereabouts. Hornblende is also scattered over the groundmass in association with biotite.

Biotite is a very common mineral in this rock. The phenocryst is commonly anhedral and tabular, being 1.5 mm. in the maximum diameter. The index of refraction is $N_m=1.627$. It gives such characteristic pleochroic colours as X=yellow, Y=Z=dark yellowish brown. Some crystals are conspicuously twisted, yielding a hericoidal structure. The inclosures in this mineral are apatite, titanite and magnetite. In the groundmass, biotite is found as minute irregular flakes of a confused aggregate.

Abundant dots of magnetite are present in the groundmass together with hornblende or biotite. Even the largest crystal is 0.2 mm. in diameter. In almost all thin sections prismatic or granular crystals of apatite can be seen. Euhedral crystal is a combination of prism and pyramid. Its longer diameter is generally less than 0.14 mm. Titanite is primary or secondary constituents. The secondary variety has been derived in the chloritization of biotite, but it is not so abundant as epidote. Quartz is an unimportant ingredient in the groundmass. Epidote is always granular, the largest crystal of it being 0.9 mm. ×

0.6 mm. in size. It is mostly associated with biotite. In many thin sections, chlorite is the most common secondary mineral due to the weathering of hornblende and more frequently, biotite, but calcite is unusually present. Hornblende is likely to change into a colourless mineral identified probably to be tremolite.

(ii) Spessartite:—So far as known at present, the occurrence of lamprophyre is rare in this region. It is well exposed on the exact opposite side of Mozan across the Jôsen-sui, penetrating paragneiss as well as schistose granite. There are many dykes, large or small, and the largest one is traceable about 60 meters along the cliff near the road extending to Yôei-dô (陽永洞).

The rock has a dark greenish colour and is composed of plagioclase hornblende, biotite, augite, magnetite, ilmenite, apatite, pyrite, epidote, leucoxene, chlorite, sericite, limonite, etc. (Fig. 2, Pl. III [XXIV]).

Plagioclase occurs in a lath-shaped crystal twinning after an albite or carlsbad law. When it is zoned, the nucleus is usually more acidic than the margin. The indices of refraction on (001) are as follows: $n_1=1.550$, $n_2=1.556$. Therefore, this plagioclase is andesine ($Ab_{57}An_{43}$).

Hornblende is the most important constituent in spessartite. Its crystal is always anhedral or subhedral, and the prismatic crystal is 1 mm. in the maximum length. It occasionally includes the irregular patches of augite crystals and partly passes into biotite. The pleochroism changes as follows: X=light yellow, Y=yellowish green, Z=bluish green.

Biotite is found' in a subordinate amount. Augite is more abundant than biotite, and occurs in a close association with hornblende. The largest crystal is 0.35 mm. in longer diameter. Ilmenite or magnetite takes a skeletal or granular form, and is scattered in the thin section, the former showing a transition to leucoxene. Apatite and pyrite are rare. Epidote and chlorite are derived from hornblende or biotite, while sericite is an alteration product of plagioclase.

The exposure of spessartite is quite indifferently found from those of diorite-porphyrite, so that it is impossible to know which the earlier intrusive is. Diorite-porphyrite seems, however, to have been intruded later than hornblende-biotite-quartz-diorite, because the latter is sometimes traversed by the former dyke.

Basalts:—Basalt flows are found at several places. In general, the exposures are highly cliffed along the Jôsen-sui and Tôman-kô where they cover the old river beds. As will be understood from field evidences there are two kinds of lava, titaniferous augite-olivine-basalt and porphyritic plagioclase-olivine-basalt. Titaniferous augite-olivine-basalt is underlain by gravel bed or schistose granite, and it is older than porphyritic plagioclase-olivine-basalt. The present exposures of titaniferous augite-olivine-basalt are erosion remnants, and they are traceable down to the vicinity of Kainei. It is evident that this basalt flow was brought down from the still upper course of the Tôman-kô and filled up the old river bed. Such a lava flow was dissected by the rejuvenated river, and the surface had been subsided about 100 meters before the last eruption took place somewhere near Mozan.

(i) Titaniferous augite-olivine-basalt:—Titaniferous augite-olivine-basalt is well exposed along the Jôsen-sui and Tôman-kô. At the opposite side of Mozan, it covers the gravel bed which is preserved on the cliff 70 to 90 meters above the present river surface near Mozan. There are also detached exposures at Kyogen-dô (虛彥洞). The maximum thickness of these lava flows is respectively 8 meters and 4½ meters in the vicinity of Mozan and Kyogen-dô.

It is a porous rock with a dark gray or gray colour, consisting of plagioclase, olivine, titaniferous augite, magnetite and apatite (Fig. 3, Pl. III [XXIV]). Lath-shaped plagioclase belongs to acidic labradorite, as shown by the following indices of refraction measured on (001), viz., $n_1=1.556$ and $n_2=1.562$. There are, however, two stages of crystallization: the earlier lath-shaped crystals are more basic than the interstitial variety. Besides plagioclase, the remarkable constituents are olivine and augite. Augite belongs to a titaniferous variety. It is faintly pleochroic: X=light purplish brown, Y=light yellowish brown, Z=light brownish purple. The absorption is $Z>X>Y$, and the extinction angle, $Z\wedge c$, is 38° or thereabouts. Magnetite is abundantly found in the groundmass where it takes a granular, skeletal or platy form. Apatite is a minor constituent.

(ii) Porphyritic plagioclase-olivine-basalt:—This basalt is the youngest extrusive exposed around Mozan where it rests upon the paragneiss or schistose granite, 3–7 meters above the present river bed of the Tôman-kô. The basalt flow is 3–13 meters in thickness.

It is a very porous rock with a dark gray or black colour and a coarsely porphyritic texture, being usually composed of plagioclase, olivine, augite, magnetite, glass, etc. (Fig. 4, Pl. III [XXIV]), and always have a very fresh appearance. There are many large phenocrysts of plagioclase and olivine. The most conspicuous feature of this rock is the occurrence of the large plagioclase crystal which is often 1.5–2 cm. in longer axis. It has a vitreous lustre and occurs in the subhedral or anhedral rectangular forms. The indices of refraction on (010) are estimated as follows: $n_1=1.556$ and $n_2=1.560$. Hence this plagioclase belongs to an acidic labradorite. The plagioclase in the groundmass shows a lath-shaped habit and is 0.25–0.4 mm. in length. It is more acidic than the phenocryst. Olivine is the most common ferro-magnesian mineral. The phenocryst is often euhedral and more than 2 mm. in diameter. The minute granular crystals of groundmass are always found together with augite and magnetite. Augite and magnetite are much less than olivine: glass is negligible in some specimens. Besides such constituents, there is a feldspar which was identified as anorthoclase.

The specimens collected along the Jôsen-sui were chemically investigated by T. Kôno. The result of the chemical analysis is shown in the following table.

Wt. %		Norm		Ratio
SiO_2	48.24	Orthoclase	8.90	
TiO_2	5.20	Albite	26.20	$\frac{\text{Sal.}}{\text{Fem.}}=1.57$ (Class III)
Al_2O_3	15.95	Anorthite	16.96	
Fe_2O_3	2.18	Nepheline	8.24	$\frac{L}{F}=1.58$ (Order 7)
FeO	6.96	Diopside	24.87	
MnO	—	Olivine	1.01	$\frac{Na_2O'+K_2O'}{CaO}=1.56$ (Rang 3)
MgO	3.75	Haematite	2.24	
CaO	9.86	Ilmenite	9.88	$\frac{K_2O'}{Na_2O'}=0.20$ (Subrang 4)

K_2O	1.47	Apatite	0.31
Na_2O	4.95		98.61
P_2O_5	0.15		
Ig. loss	1.27		
Total	99.98		

The most characteristic feature in the result of this chemical analysis is the abundance of Na_2O. It may probably be due to the presence of anorthoclase.

THE HISTORY OF IGNEOUS ACTIVITIES,

Although the most characteristic geological feature of the Mozan iron-bearing district is the predominance of igneous rocks, the geological age of their intrusion or extrusion has not exactly been known.

Among them schistose granites are the the oldest intrusives and might have been intruded into several times. They are found in various modes of occurrence, but the main body here is probably a batholith. Such intrusions undoubtedly took place after the accumulation of the metamorphosed sedimentaries distributed sporadically in this region. Some isolated masses of these sediments might be a roof pendant of the huge igneous body mentioned above. Moreover, such metamorphics frequently indicate a very complicated structure due to the lit-par-lit injections of a red schistose granite which is nearly free of ferro-magnesian minerals. The similar granitic mass exposed between branched zones of the iron formation may be a marginal facies of batholith or a satellitic intrusive from it. The same explanation is probably accepted for the mode of intrusion of augen-gneiss or schistose porphyritic granite at Hinshi-dô or somewhere near Goryû-dô.

As is shown in the general geological map Chôsen, nearly whole parts of N. Kankyô-dô (咸鏡北道) are made up of granites and schistose granites. Some of them were, in the Meisen-Kisshû (明川—吉州) districts, intruded through the Matenrei System belonging to the Pre-Cambrian. According to I. Tateiwa[1] the so-called Meisen schistose

---

1) I. TATEIWA :—Geol. Atlas of Chôsen, No, 4, 1925, p. 5.

granite is identified also to be of the Pre-Cambrian (?) in age. S. Kawasaki[1] states that the granites and gray granite-gneisses of the Tansen-Rigen-Hokusei (端川—利原—北青) regions are still older than the so-called Chôsen System (Cambrian ?) near the Rigen Mine. However, these igneous activities are considered more complicately by Y. Kinosaki[2]. He believes that the intrusions were repeated from the Pre-Cambrian up to the Cretaceous.

In the Mozan district the intrusive relations between granitic rocks are analogously expected to be complicate, but they have not yet been investigated up to the present. Not only here, but also in the frontier regions, including many counties such as Kainei (會寧), Shôjô (鍾城), Onjô (穩城), Keigen (慶源), and Keikô (慶興), granitic rocks are very commonly observed. They have sometimes more or less a schistose structure, finally passing into a characteristic schistose granite which may be a peripheral facies of huge intrusive bodies. The schistosity of granitic masses thus increases more and more toward the contact part. The transition between non-schistose and schistose varieties is gradual in almost all cases, and it is particularly characteristic between augen-gneiss and porphyritic granite. S. Kawasaki[3] similarly found out the presence of a more or less distinct foliation near the borders of granite in the Matenrei district, and there the foliation coincides with the strike of the neighbouring Matenrei System.

Such a tendency can especially be seen in the northwestern corner of the Kainei-gun where schistose varieties are obviously younger than the Hekijô (碧城) formation[4]. In many respects this formation is akin

---

1) S. KAWASAKI:—Mica in Chôsen. Bull. Min. Surv. Chôsen, Vol. 1, Part 2, p. 40, 1910.

2) Y. KINOSAKI:—Geol. Atlas of Chôsen, No. 14, 1932, pp. 8-9.

3) S. KAWASAKI:—op. cit., pp. 26-27.

4) The Hekijô formation is well exposed in the mountainous area between the Gohô-san (五峰山) range of Kainei-gun and Shôkaku-dô (松鶴洞) of Mozan-gun, farther extending into the Manchurian territory. It is composed of conglomerate, hornfels, black clay slate, gray sandstone, graphite-schist, chlorite-schist, limestone, amphibolite, etc. The conglomerate bed probably builds up the basal part of this formation and contains abundant lenticular pebbles of granite together with quartzite and black clay slate. The analogous types of sediments are also traceable farther up to the northern area of Kainei-gun. They are separately exposed at Chûtô (中島), Seisô-toku (靑草德), Kakenhô (花見峰), and Kôreichin (高麗鎭). The sediments here are likely to be less metamorphosed northward, and they are intercalated by a fusulina-bearing bed at Tômaku-dô (陶幕洞) of Kainei-gun and elsewhere in Keigen-gun. In this way, some metamorphosed sedimentaries here may belong to the Permo-Carboniferous.

to those exposed at Goryû-dô or Hinshi-dô, and they are found close to each other. The field evidences thus obtained are likely to suggest that these formations were originally connected altogether, and most granites or schistose granites of the Mozan district might not be older than the Permo-Carboniferous in age. The probable occurrence of the similar granites is also considered by Y. Kinosaki[1] in the Koho-Gosokuri (古堡—鼇足里) districts, and an enormous diastrophism happened soon after the deposition of the Heian System (Triassic-Upper Carboniferous) can not be neglected in connection with these facts, because it was followed by some extensive granitic intrusives[2].

It is, however, very noteworthy that there are abundant pebbles of biotite-granite and other varieties in the metamorphosed conglomerates exposed at Goryû-dô and the southwestern corner of Kainei-gun including Gohô-san and Kyûsetsu-rei (九折嶺). This is undoubtedly an evidence of granitic intrusions in a still older geological age, but the exposures of such granites are not exactly known in the area under consideration.

After the enormous intrusions of red granite and its allied varieties, frequent injections of quartz-diorite, diorite-porphyrite, etc. took place through the consolidation cracks of the batholithic mass and invaded sediments. These igneous activities, without doubt, continued for long periods. Although the exposure of quartz-diorite is not remarkable in this field, it is an important intrusive in the neighbouring district, often changing into a schistose variety in the peripheral zone. It seems to be older than the granite-porphyry found extensively in the northern half of Eihoku-men (永北面). There are also some remarkable examples of composite dykes consisting of quartz-diorite and diorite-porphyrite in the vicinity of Goryû-dô, the former being penetrated by the latter. It is still questionable whether this quartz-diorite was subjected to the Post-Jurassic disturbance or not.

Lamprophyres and diorite-porphyrites are very common hypabyssal rocks in Korea. Some of them are later than the Jurassic, but they

---

1) Y. Kinosaki:—op. cit. p. 8.

2) In the Kaisen district of S. Heian-dô the folded Heian System was intruded by large granitic masses up to the Green Series.

have never been found in the Tertiary area. The frequency of these rocks is well known in the Koho-Gosokuri districts where they are supposed to have been injected in the Cretaceous-Upper Jurassic. Analogous rocks are also frequently seen in the Mozan district and vicinity. Diorite-porphyrite is the most predominant rock of them, being younger than quartz-diorite or granite-porphyry, but older than quartz-porphyry poured out somewhere near the Jadô (蛇洞) valley of Hôkei-men (豐溪面). Further evidence is lacking here as to their exact geological age and it may still be impossible to compare them directly with those of other regions. There is, however, no reason to deny the possibility of the magmatic activities associated with the Post-Jurassic disturbance even in the frontier area.

An unusual eruption of basalt flows seems to have been preceeded by a large upheaval movement in the Post-Tertiary Period. It took place particularly in the vast area including N. Korea and Manchuria. These lavas partly filled up the old river beds of the Tôman-kô near Mozan, extending up to the extreme north. The eruption was, at least, repeated thrice, and it was most extensive in the beginning. In this district some of the lavas are still preserved, and the volcanic activities were undoubtedly going on up to a recent period.

A TREATISE ON THE TECTONIC DISTURBANCE.

So far as can be infered from the topographical and geological evidences, the extensive area of N. Kankyô-dô, particularly that of the frontier region, has been subjected to an enormous diastrophism twice or thrice.

The displacements of large also small scales are distinctly observed in the Kainei-Shôjô district where the monotonous land is traversed by many faults. Some of them are typical step faults, while the others are found as reverse types. The coal fields here are thus built up of a complicate aggregate of many blocks. In addition to this, one of the most characteristic features is indicated by the remarkable meanders of the Tôman-kô between Kainei and Mozan. This frontier river hollows out deep gorges here and there in the huge granitic masses, showing that its course might have been followed to the fractures. A similar tendency is also seen in many of its tributaries.

There are several systems of such fault lines in the Mozan district. Their trends are respectively NNE-SSW, NE-SW, NW-SE, NNW-SSE, and E-W, most of them being parallel to the present river course of Tôman-kô and Jôsen-sui. These displacements are not easily traceable in the granitic exposures, but they are frequently found in the area of the metamorphosed sedimentaries exposed at Nikken-dô, Fukushahei, Rokusho, and elsewhere. Even the disappearance of the iron formation as well as the predominance of the talus formation along the valley extending northeast from Nikken-dô may be due to the same cause.

As to the geological age of the dislocation, only a few reliable evidences are to be obtained in the Mozan district. However, it is highly probable that the last disturbance simultaneously took place with that of the Kainei-Shôjô coal fields1) and, therefore, corresponds to the block movement which happened after the accumulation of the Meisen (明川) Group in the Meisen-Kisshû district2). This was undoubtedly carried out before the great eruption of the basaltic lavas which extensively cover the densely forested regions including North Korea and Manchuria.

CHARACTERS OF HAEMATITE-MAGNETITE-QUARTZITE AND HAEMATITE-MAGNETITE-QUARTZ-SCHIST.

As far as is known as present, the ferruginous rocks here are almost nearly represented by haematite-magnetite-quartzite and haematite magnetite-quartz-schist, the so-called banded iron ores. In various respects these rocks are similar to those in several districts of Korea and Manchuria, such as Chûshû (忠州), Zuizan (瑞山), An-shan (鞍山), Kung-chang-ling (弓長嶺), Miao-erh-kou (廟兒溝), etc. where they are called ferruginous quartzite3), haematite-magnetite-quartz-schist4), haematite or magnetite-

---

1) In the Kainei-Shôjô coal fields the sills or laccoliths of trachydolerite injected into the Miocene (?) sediments are much displaced.

2) I. Tateiwa:—Geol. Atlas of Chôsen, No. 4, 1925, pp. 5-6.

3) H. Murakami:—Geology of the An-shan Iron Mine District, S. Manchuria, 1922, p.

4) 14. K. Tsuru:—Geology and Ore Deposits of the Miao-erh-kou Iron Mine District, (Japanese) Rep. Ryojun Coll. Eng., vol. 1, No. 3, 1931, pp. 153-154.

gneiss, haematite or magnetite-schist[1], banded feldspar-bearing magnetite quartzite[2], etc.

(1) Megascopical and Microscopical Characters:—They are mostly very hard and banded rocks with a dark gray colour. This structure is due to the alternate arrangement of quartz and magnetite or haematite. It is more distinctly observed on the polished surface. There is also a massive type without any banded structure. These varieties gradually pass each other, showing frequent structural or textural variations, from coarse to fine, in the exposure. Although there are some local changes in their mineral constituents, they are usually composed of a varying amount of haematite, magnetite, quartz, hornblende, actinolite, tremolite, and apatite (Fig. 2, Pl. IV [XXV]).

Magnetite is generally more abundant than haematite, both minerals occurring together in varying proportion. It is found in irregular patches or rectangular crystals which are often connected each other in a parallel arrangement. In polished sections it gives a white colour and pitted surface, and can not be distinguished from haematite without using hydrochloric acid. The large patch is often more than 3 mm. in longer diameter, whereas the rectangular crystal is mostly very small.

Haematite is always closely associated with magnetite. In this case both minerals are sharply bordered. Haematite is usually scattered in very irregular patches (Fig. 4, Pl. IV [XXV]) as is shown by magnetite, but sometimes it forms a narrow rim surrounding the latter mineral (Fig. 3, Pl. IV [XXV]). Hence, the haematite was probably formed later than the magnetite. The interstices of these minerals are filled up by a mosaic aggregate of quartz grains. In the thin section large quartz grains are cemented by minute ones and they commonly indicate a remarkable wavy extinction.

Sometimes hornblende is abundantly found together with haematite and magnetite, but it is not associated with actinolite or tremolite. The crystal generally occurs in a confused aggregate and anhedral form.

---

1) T. Ichimura:—On the Iron-bearing Formation and its Enriched Ore Bodies of Kung-chang-ling, S. Manchuria, (Japanese) Korean Min. Asso., Vol. V, 1922, p. 415.

2) S. Kawasaki:—Mineral Resouces of Chôsen (S. Chûsei-dô), Vol. IX, 1921, pp. 172-176.

When it is prismatic, this mineral is elongated along c-axis. The largest crystal is 1.4 mm. or thereabouts. The indices of refraction are $n_1=1.640$ and $n_2=1.655$ on (110). It is moderately pleochroic, viz., X=light yellow, Y=yellowish green, Z=bluish green. The absorption is $X<Y<Z$. The extinction angle, $Z \wedge c$, is 20°, and the optical character is negative. In other specimens, actinolite is very frequently present. This mineral is usually anhedral, but occasionally subhedral. Prismatic or needle-shaped crystals are also observed, forming a fibrous aggregate. Comparing with hornblende it is very faintly pleochroic and nearly colourless. The scheme of pleochroism is as follows: X=colourless, Y=light greenish yellow, Z=light green. Birefringence colour is weaker than hornblende, and maximum extinction angle, $Z \wedge c$, is 18°. The optic character is negative. Tremolite is rare.

One of the most remarkable features is the frequent occurrence of apatite which occurs in a rounded or stout prismatic form. The largest crystal in the thin section is measured to be 0.6 mm. in longer diameter.

Under the microscope the banded structure is not so obvious as in the hand specimens. It is only shown by a gradual increase or decrease of haematite and magnetite together with amphiboles.

The writer has hitherto examined many thin sections of the so-called banded iron ores collected from several localities of Korea and Manchuria. Some of them are entirely free of amphiboles, but others contain a minor amount of actinolite or tremolite or hornblende. Actinolite or tremolite can be seen in the specimens from Kung-chang-ling, Miao-erh-kou, An-shan of Manchuria, whereas hornblende is present in the banded ores from Pa-pán-ling (八盤嶺), Wai-t'ou-shan (歪頭山) of Manchuria, and Goryû-dô (五龍洞) of N. Kankyô-dô. The similar type of banded ores is also known at Syd Varanger of Norway[1]. Sometimes apatite is present in the specimens from Kung-chang-ling and Miao erh-kou, but it does not occur so frequently as in the amphibole-bearing varieties from Mozan. The abnormal occurrence of this mineral seems to give some suggestion as to the origin of such ferruginous rocks.

---

1) Per Geijer:—Some Problems in Iron Ore Geology in Sweden and in America, Eco. Geol., Vol, X, 1915, pp. 306-313.

(2) Chemical Character: - Although haematite-magnetite-quartzite and haematite-magnetite-quartz-schist are found in an enormous amount, most of them are chemically low in iron but high in silica. The writer has collected many specimens from various parts of the exposure, and they have chemically been analysed at the Mitsubishi Iron and Steel Works. The results indicate that iron percentage ranges from 10.81 to 49.85, whereas silica percentage is between 71.06 and 29.58. In these cases most specimens contain 35–45 percent of iron and silica. Indistinctly banded or massive types are usually very low in iron but high in silica. They are conveniently called haematire-magnetite-quartzite.

It is also noticeable that sulphur and phosphorus are in a high percentage. The phosphorus is undoubtedly due to the presence of apatite. As will be understood from the following table, such abnormal proportions of phosphorus and sulphur are not generally shown in those from well-known localities of Korea and Manchuria.

	(1)	(2)	(3)	(4)	(5)	(6)
Fe	41.84	40.89	40.64	36.33	43.63	37.56
SiO_2	40.06	42.36	40.15	51.03	41.16	42.32
Al_2O_3	—	—	—	—	—	—
CaO	—	—	0.42	0.10	—	—
MgO	—	—	tr.	tr.	—	—
Mn	0.125	0.110	0.10	0.16	—	—
S	0.175	—	0.14	0.23	0.04	0.14
P	0.170	0.094	0.13	tr.	0.07	0.03
Ti	—	—	—	—	—	—
Cu	—	—	—	—	—	—

	(7)	(8)	(9)	(10)	(11)	(12)
Fe	37.27	36.23	38.24	35.27	40.64	36.27
SiO_2	46.00	48.08	46.00	45.40	41.18	47.36
Al_2O_3	—	—	—	—	—	—
CaO	—	—	—	—	—	—
MgO	—	—	—	—	—	—
Mn	0.10	0.07	0.10	0.18	0.21	0.18
S	0.010	0.056	0.010	0.005	0.015	0.005
P	0.014	0.021	0.011	0.044	0.26	0.032
Ti	—	—	tr.	—	—	—
Cu	—	—	—	0.003	0.002	0.004

	(13)	(14)	(15)
Fe	39.12	33.00	36.37
SiO_2	—	—	—
Al_2O_3	0.12	0.25	0.15
CaO	tr.	tr.	1.01
MgO	tr.	tr.	0.15
Mn	0.12 (MnO)	0.11	0.15 (MnO)
S	tr.	0.050	0.021
P	0.180	0.03	0.060
Ti	—	—	—
Cu	—	—	—

(1). Haematite-magnetite-quartz-schist from Mozan, Korea. (Average).
Analysed at the Mitsubishi Iron and Steel Works.

(2). Haematite-magnetite-quartz-schist from Goryû-dô, Mozan-gun, N. Kankyô-dô, Korea.
Analysed at the Mitsubishi Iron and Steel Works.

(3). Banded Haematite-magnetite ore from the Chûshû Mine, N. Chû-sei-dô, Korea1).
Analysed at the Geological Survey of Government General of Chôsen.

(4). Banded haematite-magnetite ore from the Chûshû Mine, N. Chû-sei-dô, Korea2).
Analysed at the Geological Survey of Government General of Chôsen.

(5). Banded magnetite ore from Reiden-ri (令田里), Shoen-men (所遠面), Zuizan-gun (瑞山郡), S. Chûsei-dô, Korea3).
Analysed at the Geological Survey of Government General of Chôsen.

(6). Banded Magnetite ore from In-dô (院洞), Shokin-ri (所斤里), Shoen-men, Zuizan-gun, Korea4).
Analysed at the Geological Survey of Government General of Chôsen.

(7). Haematite-magnetite-quartz-schist from Erh-tao-kou (二道溝), Kung-chang-ling, Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(8). Haematite-magnetite-quartz-schist from Huang-ni-kang (黄泥崗), Kung-chang-ling, Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(9). Haematite-magnetite-quartz-schist from Yang-mu-kou (楊木溝), Kung chang-ling, Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(10). Haematite-magnetite-quartz-schist from Miao-erh-kou (廟兒溝), Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(11). Haematite-magnetite-quartz-schist from Ta-ku-shan (大孤山), Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(12). Haematite-magnetite-quartz-schist from Wang-chia-pu-tzu (王家堡子), Manchuria.
Analysed at the Mitsubishi Iron and Steel Works.

(13). Haematite-quartz-schist from Hsi-an-shan (西鞍山), Manchuria5).
Analysed at the An-shan Steel Works.

(14). Haematite-quartz-schist from Ying-tou-yuan (櫻桃園), Manchuria6).
Analysed at the An-shan Steel Works.

(15). Haematite-quartz-schist from Tung-an-shan (東鞍山), Manchuria7).
Analysed at the An--shan Steel Works.

GENESIS OF HAEMATITE-MAGNETITE-QUARTZITE AND HAEMATITE-MAGNETITE-QUARTZ-SCHIST.

Haematite-magnetite-quartzite and haematite-magnetite-quartz-schist exposed in the Mozan iron-bearing district are associated with various

---

1) & 2) I. KOMADA:—On the Pre-Cambrian Formation in the Vicinity of Chûshû, N. Chûsei-dô; the Geology and Origin of Ore Deposits of the Chûshû Iron Mine (Japanese), Jour. Korean Min. Assoc., Vol. 5, 1922, p. 386.

3) S. KAWASAKI:—Mineral Resources of Chôsen (S. Chûsei-dô), Vol. IX, 1921, p. 174.

4) „ p. 175.

5) H. MURAKAMI:—Geology of the An-shan Iron Mine District, S. Manchuria, 1922, p. 26.

6) & 7) „ p. 27.

metamorphosed sedimentaries such as biotite-gneiss, chlorite-schist, and biotite-schist. They are intruded by an enormous granitic mass which is a schistose granite. As there are some xenoliths of haematite-magnetite-quartz-schist along the contact of schistose granite, the intrusion here took place later than the deposition of banded iron ores (Fig. 1, Pl. IV [XXV]). It is very remarkable that all ferruginous rocks contain either hornblende or actinolite but rarely tremolite, and are quite free of biotite or feldspars. Among them the first three minerals are almost entirely absent in the biotite-gneiss or biotite-schist associated with ferruginous rocks, whereas the last two are their important constituents. Hence, the original rocks of haematite-magnetite-quartzite, haematite-magnetite-quartz-schist, etc., were probably much different from these argillaceous sedimentaries in chemical and mineralogical compositions. In addition, they are likely to have been orginally highly quartzose, and the unfavourable conditions as to their metasomatic origin are also indicated by the almost uniform structure as well as the extensive distribution and enormous thickness of the exposure. Furthermore, garnet and other contact minerals, which are often abundant in Kung-chang-ling and Ying-tou-yuan, have not hitherto been found here in association with the iron formation.

So far as is known in the present investigation, the mode of occurrence and nature of the banded haematite-magnetite rocks in the Mozan iron-bearing district partly resemble those of the Lake Superior region including Minnesota, Michigan, and Wisconsin. A similar type is also known in Itabira de Matto Dentro of Minas Geraes of Brazil1). About ten years ago, Murakami2) closely studied about the structure and general occurrence of haematite-quartz-schist exposed extensively in the An-shan Mine district and concluded that it was originally precipitated by a biochemical process in shallow waters such as swamps and lagoons. His hypothesis is much different from Komada's idea3) that the iron

---

1) E. C. Harder:—The "Itabirite Iron Ores of Brasil". Eco. Geol., Vol. IX, 1914, pp. 106-111.

2) H. Murakami:—Geology of the An-shan Iron Mine District, S. Manchuria, 1922, p. 32.

3) I. Komada:—On the Pre-Cambrian Formation in the vicinity of Chûshû, N. Chûsei-dô; the Geology and Origin of Ore Deposits of the Chûshû Mine (Japanese), Jour. Korean Min. Assoc., Vol. 5, 1922, pp. 391-392.

formation of the Chûshû Mine is mechanically concentrated products of magnetite and quartz sands. As proposed by Komada in this way, it is believable that some bedded iron deposits arise in the mechanical concentration of magnetite sands. However, it would usually not be expected on a large scale, unless there were a particularly favourable condition. Even in the exceptionally extensive deposits of magnetite sands found in the Funkawan (噴火灣) district of Shiribeshi (後志) Prov., the Kuji (久慈) district of Iwate (岩手) Pref., the Shimokita (下北) district of Awomori (青森) Pref., etc., they are mostly very thin compared with their horizontal distribution. In addition, the results of many chemical analyses carried out on the magnetite sands from well-known localities of Japan show that they are mostly highly titaniferous. Such a chemical character is not known in the banded haematite-magnetite rocks from the Mozan district as well as other several localities of Korea and Manchuria.

An interesting feature of these rocks is shown by the presence of phosphorus. It is extremely low in the iron ores due to the hydrothermal process or contact effect, but is high in such ores of a sedimentary origin as oolitic haematite or limonite. The haematite-magnetite rocks of the Mozan iron formation are remarkable in the percentage of phosphorus, suggesting that they were probably precipitated under the co-operation of some organisms as supposed by Murakami. But their prominent banded structure will need a further consideration. The writer has attributed it to a rhysmic precipitation from the colloidal solution of iron and silica1). This has also been experimentally proved by Moore and Maynard2). This would be carried out on a large scale, if a large amount of iron and silica were transported to the sea as pointed out by Gruner3)

---

1) T. Ichimura:—Koreo-Manchurian Pre-Cambrian Banded Iron Ore Deposits and their Enriched Ore Bodies (Japanese), Jour. Geol. Soc. Tôkyô, Vol. 28, 1921, pp. 246-247.

2) E. S. Moore and J. E. Maynard:—Solution, Transportation, and Precipitation of Iron and Silica, Eco. Geol., Vol. 24, 1929, pp. 285-286.

3) J. W. Gruner:—The Origin of Sedimentary Iron Formations: The Biwabik Formation of the Mesabi Range, Eco. Geol., Vol. 17, 1922, p. 455.

Gruner states "If an average of 3 parts of iron per million is assumed for the water (which would be in keeping with the analyses), the Amazon River in 176,000 years could carry 1,940,000 million metric tons of iron to the sea.......the amount assumed for the Biwabik formation. The amount of silica carried would be correspondingly large."

and Clarke(1). Moreover, many facts have been shown by Moore(2), Simpson(3), etc., that rivers or streams or lakes sometimes contain iron in fairly remarkable quantity. Some periodic change of the climatic condition may be also necessary in this type of precipitation.

Iron formation thus formed is likely to have been subjected intensely to the contact and dynamic metamorphisms. Under such conditions primary iron ore minerals were wholly recrystallized to haematite or magnetite, and hornblende, actinolite or tremolite were formed by similar processes. Murakami(4) states that the primary iron minerals of the Anshan iron formation were hydrous iron oxide precipitated by a biochemical process, but, in the Mozan iron formation, there is no exact evidence to confirm it at present.

POSSIBILITY OF ENRICHED ORE BODIES.

It is very desirable for economic purposes to find the high grade ore. Therefore, enriched ore bodies were hitherto closely prospected throughout the enormous exposure of the Mozan iron formation.

The iron formation here is intruded by the granitic mass and is often associated with amphibolite, as is shown in the Miao-erh-kou Mine district, but there is no trace of enriched bodies supplied later by the intrusions of these rocks. It seems also to be free of secondary products enriched by the partial leaching of silica due to the circulation of the ground water, although such examples are very common in the An-shan Mine district, Kung-chang-ling, or other localities. Furthermore, the writer collected many types of specimens from various parts of the exposure to confirm whether the high grade ore is really present or not. These abundant specimens were sent to the Mitsubishi Iron and Steel Works where they were chemically investigated. The results thus obtained indicate that even the best specimen does not contain above 50% of iron and is still very high in silica. So far as

---

1) F. W. CLARKE: - Data of Geochemistry, U. S. Geol. Surv., Bull. 770, 1924, p. 119.

2) E. S. MOORE:—Econ. Geol Vol. 5, 1910, p. 533; 18th Rept. Ont. Bur. of Mines, 1909, p. 192.

3) E. S. SIMPSON:—Geol. Mag., Vol. 49, 1912, p. 405.

4) H. MURAKAMI:—The Iron Ore Deposits of Si An-shan, S. Manchuria, (Japanese), Jour. Geol. Soc. Tôkyô, Vol. 26, 1919, p. 422.

known in the field observation, the nearly whole parts of exposure are likely to be built up of low grade ore, viz., the so-called banded ore or massive variety. However, the iron formation shows a somewhat deep downward extension in the western area, and it is partly buried under the talus or soil without any exposure. Hence, it is reasonable to believe that some enriched ore bodies will be found in future prospecting.

SOURCES OF IRON.

As has been explained elsewhere, the ferruginous rocks of the Mozan iron-bearing district were accumulated in an enormous thickness and extensive area. Here the most questionable is the original source of iron. It is very hard or nearly impossible to trace back the past condition in such metamorphosed sediments. Therefore, various hypotheses have hitherto been advanced to accout for this subject even in the Lake Superior region where the iron formation was well studied. Van Hise1) supposed, after the close investigation of the iron formation in the Lake Superior region, that it was derived largely from the oldest basic igneous rocks. In this case the iron leached by underground waters can be carried to the sea as carbonate, or partly as sulphate solution. Accordingly, limonite is expected to be precipitated in the beginning, and then it may possibly be reduced to ferrous carbonate by organic matter. C. K. Leith's hypothesis2) is somewhat different from that mentioned above: he suggested that the iron was brought to the surface by the igneous intrusion and either contributed directly to the ocean by hot magmatic waters or surface weathering. E. S. Moore3), however, doubted the possibilities of abundant contribution of iron due to the magmatic emanation and attributed it to the weathering action yielding laterite. H. Murakami4) proposed somewhat of a similar assumption on the source of iron formations in the An-shan mine district. He considered that the iron was mainly extracted in the decomposition of rocks

---

1) W. Lindgren:—Mineral Deposits, 1928, p. 410.

2) C. K. Leith:—Iron Ores of Canada, Eco. Geol., Vol. 3, 1908, pp. 276-291.

3) E. S. Moore:—The Iron Formations of Belcher Island, Hudson Bay, Jour. Geol., Vol. 26, 1918, p. 412.

4) H. Murakami:—op. cit. pp. 29-30.

of the basement complex, such as granite, gneiss, amphibolite, and crystalline schists with some basic intrusives, which are widespread in South Manchuria. According to his investigation, the occurrence of the basic green-schist-complex, viz., diabasic rocks, chlorite-schist, and biotite-schist in association with haematite-quartz-schist, is also regarded here as of importance.

In the Mozan iron-bearing district, ferruginous rocks are exposed together with metamorphosed sedimentaries, being intruded by various kinds of intrusives. The rocks are only isolated remnants resting upon the schistose granite which is extensively distributed in this region. The geological age of the schistose granite here is probably younger than that of metamorphosed sedimentaries. Ferruginous rocks are closely associated with biotite-gneiss or biottte-schist intercalated by hornblende-biotite-gneiss, chlorite-schist, etc., and there is no evidence of unconformity between them. As can be infeied from the geologic structure, ferruginous rocks may be of lower horizon compared with other metamrophosed sedimentaries. A similar iron formation is also known along the Goryû-dô valley where it seems to be exposed in the uppermost horizon of less metamorphosed sediments consisting of hornfels, biotite-schist, quartzite, schistose conglomerate, etc. Both iron formations are, however, indifferently exposed, and therefore, they can not be correlated to each other at present.

So far as infered from the field evidence, these rocks belong to the oldest group here in the frontier region. In this way, the materials of the metamorphosed sedimentaries under consideration were probably transported from other regions. The extensive area including North Korea and Manchuria is built up of the so-called gneisses. It is quite probable that it is composed of various types of metamorphosed intrusives which are partly covered by thick basalt flows without any exposure. Some of these metamorphics may be still older than those of the Mozan or Goryû-dô iron-bearing districts. Hence, it is believable that the remarkable amount of iron was extracted from these rocks, particularly basic types, during the surface weathering or erosion, and it was carried to the shallow sea. The iron minerals were accumlated here to an enormous thickness under some favourable conditions. From this point of view, the writer's consideration on the sources of iron largely agrees with that of H. Murakami.

SUMMARY.

(1) The Mozan iron-bearing district is mainly built up of various kinds of metamorphosed sedimentaries and intrusives. Some of them are intruded by quartz-diorite and hypabyssal rocks, whereas the others are covered by basalt flows and Quaternary sediments.

(2) Metamorphosed sedimentaries are composed of ferruginous rocks, biotite-gneiss, hornblende-biotite-gneiss, biotite-schist, chlorite-schist, etc. which were subjected to the enormous intrusion of granitic magma. They are also much disturbed by folding and faulting.

(3) Ferruginous rocks are chiefly represented by haematite-magnetite-quartz-schist and haematite-magnetite-quartzite. They are mostly the so-called banded iron ores.

(4) Ferruginous rocks are exposed in a large extension and enormous thickness, gradually thinning out northeastward. They are partly separated into two zones and deeply project into schistose granite at the western end, but only detached remnants are known in the eastern area.

(5) Haematite-magnetite-quartz-schist and haematite-magnetite-quartzite usually consist of haematite, magnetite, quartz, hornblende, actinolite, apatite, etc. They are generally low in iron but high in silica. Moreover, one of the most remarkable features of these rocks is the high proportion of phosphorus due to the presence of apatite.

(6) So far as is known in the field observation, the exposure shows a nearly uniform feature without any trace of enriched ore bodies. However, further prospecting is, of course, necessary to confirm whether enriched parts are really absent or not.

(7) The iron formation here is evidently of sedimentary origin, and it seems to have been precipitated from colloidal solution of iron and silica. In this case the iron was extracted from various kinds of

rock subjected to the weathering and was transported to the sea where it was accumulated together with silica to an enormous thickness.

(8) The primary iron minerals are absolutely absent at present, but there is no doubt that haematite and magnetite are the recrystallized products due to the contact or dynamic metamorphism.

(9) In many respects the Mozan iron formation is similar to those of An-shan, Miao-erh-kou, Kung-chang-ling, Chûshû, Zuizan, and others.

(10) It will also be an important source of iron in future.

PLATE I [XXII].

Explanation of Plate I [XXII].

1. A north-west view from the ridge near Rokusho. This picture shows the ridge where two zones of ferruginous rocks are exposed. One of these forms the back bone to the right, whereas the other is found on the slope, both extending from north-east to south-west.

2. The upper course of the Jôsen-sui seen from the ridge near Nikken-dô. The nearest slope in front is almost built up of ferruginous rocks in association with biotite-gneiss, chlorite-schist, etc. in its lower half.

3. Looking down westwards from the back bone of the ridge where the ferruginous rocks are well exposed.
(1) Jôsen-sui, (2) Tôman-kô, (3) Mozan, (4) Manchurian territory.
The ferruginous rocks are partly exposed on the thickly forested ridge in front.

Fig. 1.

PLATE II [XXIII].

Explanation of Plate II [XXIII].

1. Biotite-gneiss from Nikken-dô. x 60.
   A = Allanite, Ap = Apatite, B = Biotite, E = Epidote, Q = Quartz.

2. Schistose granite from Fukushahei. Crossed nicols. x 60.
   M = Microcline, O = Orthoclase, Q = Quartz.

3. Amphibolite from Nikken-dô. x 20.
   E = Epidcte, H = Hornblende, P = Plagioclase, Q = Quartz.

4. Quartz-diorite from Rokusho. x 60.
   Ap = Apatite, B = Biotite, H = Hornblende, M = Magnetite, P = Plagioclase, Q = Quartz.

Fig. 1.

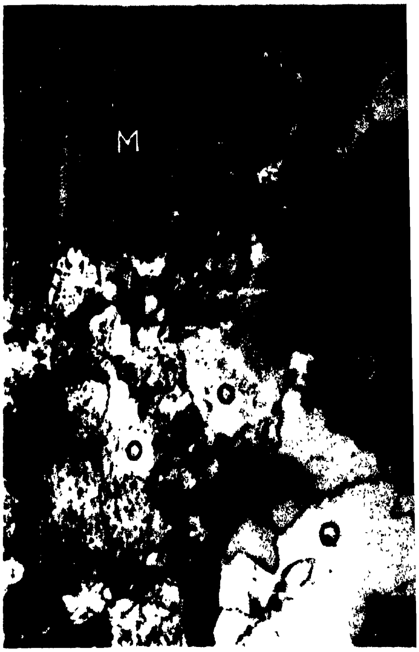


Fig. 2.

Fig. 3.

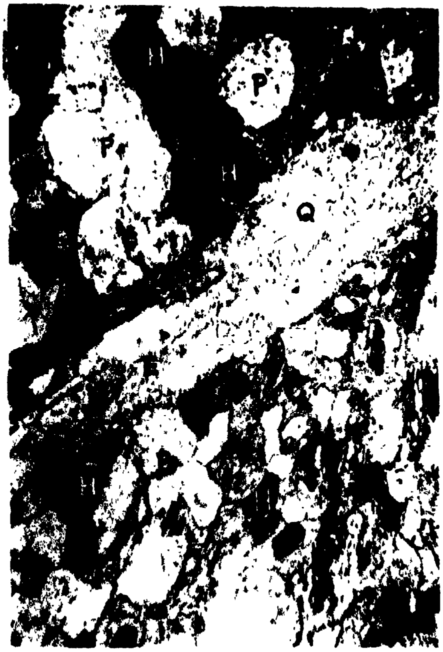


Fig. 4.

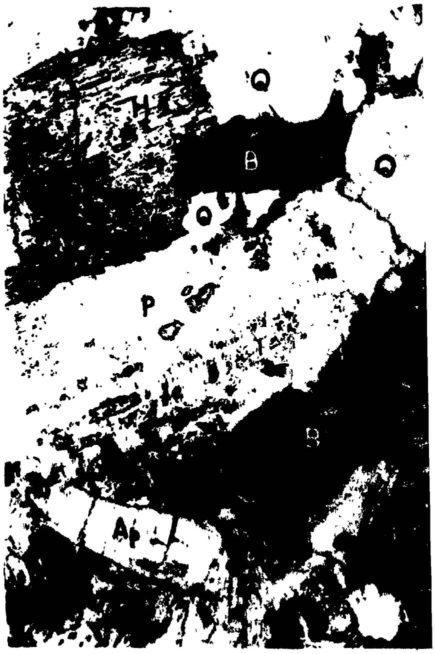


PLATE III [XXIV].

Explanation of Plate III [XXIV].

1. Diorite-porphyrite from Fukushahei. Crossed nicols. x 60.
   H = Hornblende, P = Plagioclase.
2. Spessartite from near Mozan. x 60.
   B = Biotite, H = Hornblende, M = Magnetite, P = Plagioclase T = Titanite.

3. Basalt from near Mozan. x 60.
   A = Titaniferous aguite, M = Magnetite, O = Olivine, P = Plagioclase.

4. Basalt from Mozan. x 60.
   O = Olivine, P = Plagioclase.
   This basalt sometimes contains anorthoclase as phenocryst and this mineral is also found in the groundmass.

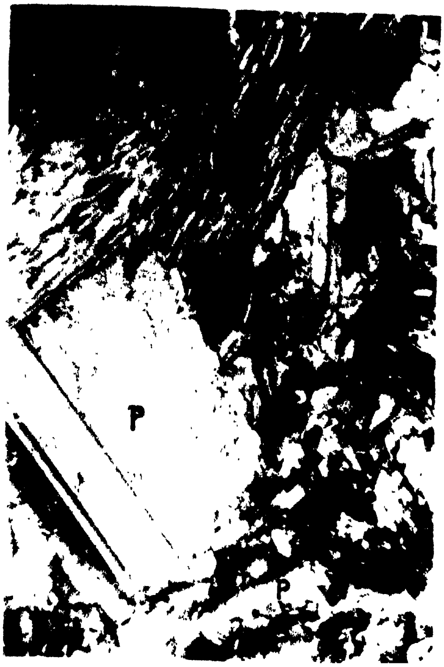


Fig. 1.

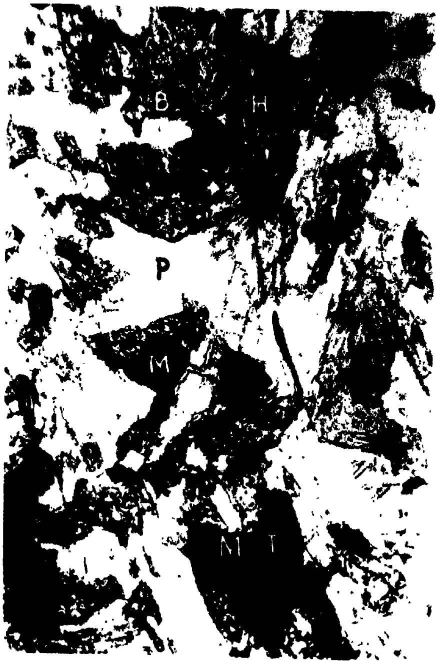


Fig. 2.

Fig. 3.

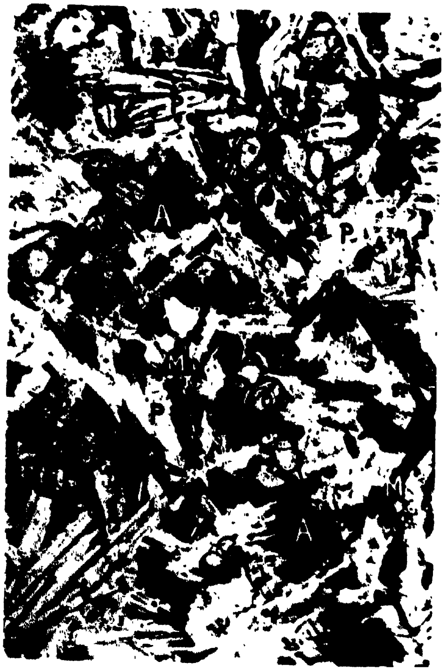


Fig. 4.

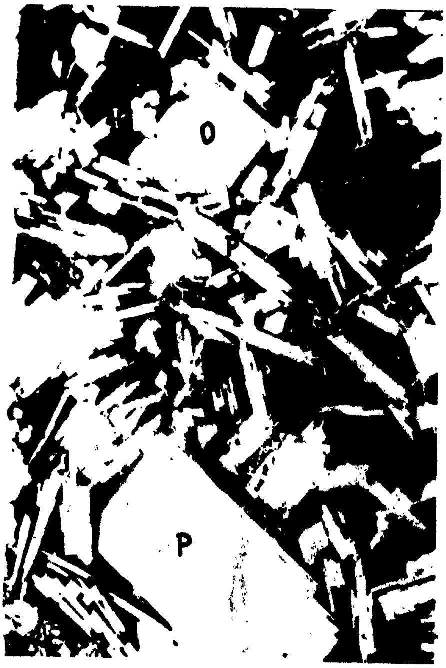


PLATE IV [XXV].

Explanation of Plate IV [XXV].

1. Contact between haematite-magnetite-quartz-schist and schistose granite (Fukushahei). x 20.
   H = Hornblende, M = Magnetite and haematite, O = Orthoclase. P = Plagioclase, Q = Quartz. The lower half is schistose granite. They show a very sharp contact.

2. Haematite-magnetite-quartz-schist from Nikken-dô. Crossed nicols. x 60.
   H = Hornblende, M = Magnetite and haematite, Q = Quartz, Besides these, there are minute apatite crystals. Hornblende and magnetite or haematite are always closely associated.

3. Magnetite crystals surrounded by the narrow rim of haematite (Nikken-dô). x 30.
   H = Haematite, M = Magnetite, Q = Quartz and hornblende.

4. A confused aggregate of magnetite and haematite (Nikken-dô). x 30.
   H = Haematite, M = Magnetite, Q = Quartz.

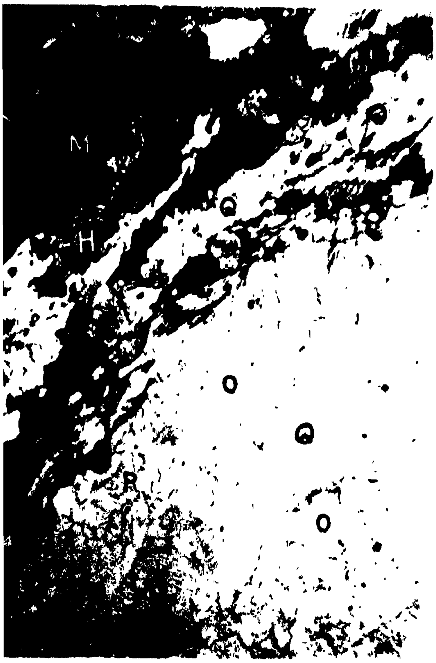


Fig. 1.

Fig. 2.

Fig. 3.

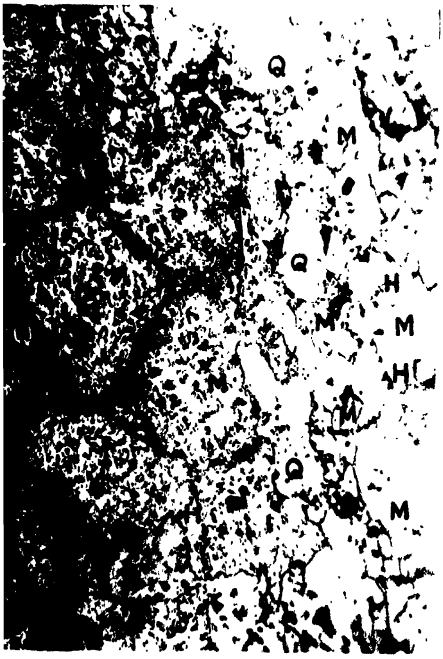
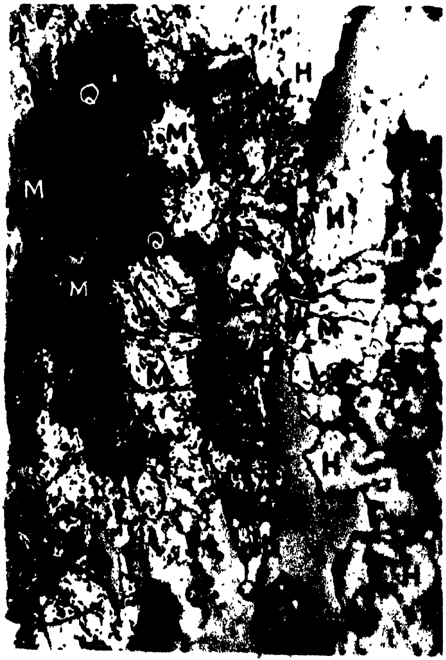


Fig. 4.



昭和八年八月二十八日印刷
昭和八年八月三十日發行

編纂兼發行者　臺北帝國大學理農學部

印刷者　穎川首
臺北市大正町二ノ三七

印刷所　株式會社臺灣日日新報社
臺北市榮町四ノ三二

購買申込所　株式會社臺灣日日新報社
臺北市榮町四ノ三二

同　丸善株式會社
東京市日本橋區通二丁目

COGNATE INCLUSIONS IN THE ANDESITE LAVAS FROM SHABÛ-ZAN OF THE DAITON VOLCANOES, TAIWAN (FORMOSA)

Takeshi ICHIMURA

With 2 Plates [XYVI-XXVII]

(Accepted for publication, March 20th, 1934)

CONTENTS

Introduction 105
Petrographical Characters of Mother-rocks... 106
Mode of Occurrence and General Features of Cognate Inclusions 108
Petrography of Cognate Inclusions... 109
Chemical Characters of Cognate Inclusions... 112
The Formation of Cognate Inclusions 116
Alteration of Cognate Inclusions 118
Summary 120

INTRODUCTION

The frequent occurrence of cognate inclusions is one of the striking features in the hornblende-bearing andesite from the Daiton (大屯) volcanoes. It is remarkably abundant in hypersthene-hornblende-andesite or two pyroxene-hornblende-andesite from Shabô-zan (紗帽山). Such inclusion-bearing andesites poured out through the thick accumulation of agglomerate, thus builing up the huge dome-shaped mass which rises up to 643 meters above the sea-level.

They are well exposed along the route between Sôzan (草山) and Hokutô (北投). In the summer of 1929, the writer had an opportunity

[Mem of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VI, No. 6, May. 1934.]

to get many specimens from the small quarries which were already abandoned, but at the present time it may be very difficult to collect good ones.

The cognate inclusions there are always characterized by the predominance of hornblende crystals as a mafic mineral. Hence, they are not similar to those in the andesitic lavas of Sakura-jima (櫻島) or elsewhere, particularly in the presence of brown hornblende or biotite. These two minerals are probably the alteration products due to reheating, and their occurrence is very interesting in connection with the volcanic activities of the Daiton volcanoes.

The results of petrographical and chemical studies of these cognate inclusions as well as their mother-rocks are summarized in this paper. The writer wishes to thank Mr. H. Iinuma for his chemical analyses of the material.

PETROGRAPHICAL CHARACTERS OF MOTHER-ROCKS

In the beginning, it is necessary to give a short description of the andesites from Shabô-zan before the writer explains about various characters of cognate inclusions. The andesite here has two different types, the one with a gray colour, and the other, brown, the latter being an oxidized modification of the former. There is a gradual transition between them.

The composition minerals of these rocks are plagioclase, hornblende, hypersthene, augite, biotite, magnetite, haematite, apatite, and garnet (Fig. 1, Pl. I [XXVI]). They are rough and porphyritic rocks with an abundance of phenocrysts of plagioclase, hornblende, and hypersthene. Under the microscope, the groundmass generally shows an orthophyric texture due to the predominance of stumpy rectangels of plagioclase crystals.

The plagioclase usually occurs in euhedral or subhedral forms and ranges from acidic labradorite to basic labradorite with the following indices of refraction on (010), viz., $n_1=1.557—1.560$, $n_2=1.561—1.565$. It is mostly characterized by the presence of the zonal structure and turbid zone. In general, several zones with different basicities are alternately arranged, grading into other toward the interior of the crystal. When it is repeatedly zoned, the outer portion of the crystal is commonly more acidic than the interior which frequently has a rounded outline. Some crystals are wholly turbid in nucleus, and the twinning after albite or carlsbad or pericline laws is distinctly to be seen in all thin sections.

Besides plagioclase, the remarkable ingredient of these rocks is euhedral or subhedral hornblende crystals. When it is euhedral, the following faces are observed: a(100), b(010), m(110), p(101), and r(011). There are basaltic or brown varieties: they are contained respectively in gray or reddish andesites. Brown hornblende is undoubtedly an alteration product from the basaltic type, because various intermediate stages are observed between them, both being conspicuously subjected to the magmatic resorption. The largest crystal is 1 cm. or more in length. It occasionally includes somewhat rounded crystals of plagiocalse, apatite, and granular magnetite. The zonal structure is rarely known.

Hypersthene is often intimately associated with hornblebde, but is less abunbant than this mineral, showing a stout or long prismatic habit. The crystal is a combination composed of (100), (010), (110), (001) and (111), in which a(100) and b(010) are well developed. The phenocrystic hypersthene is 3 mm. in the maximum length, and it sometimes occurs in a skeletal form. As can be seen in the lavas from Shichisei-zan (七星山), Kwannon-zan (觀音山) or elsewhere, the skeleton crystal also has a shallow depression at both ends. These depressions reveal a more or less convex outline in the section cut parallel to (100). The occurrence of such an unusual form may be due to the partially imperfect growth of crystal. The hypersthene gives such a pleochroic scheme as $X=Y=$light brown and $Z=$light greenish-gray. The absorption is $Z<X=Y$. Optically it is negative. The optic plane is parallel to (010), and the acute bisectrix is perpendicular to (100). This mineral is also found as minute crystals in the orthophyric or pilotaxitic groundmasses.

Augite is found in a small amount and a minute granular or slender prismatic form in the groundmass. When it is associated with hypersthene, the former mineral always forms a narrow rim around the latter.

This fact suggests that augite was derived from hypersthene as a reaction product during the crystallization of the cooling magma. The phenocrystic augite is 1 mm. × 0.5 mm. in the maximum size and is less commonly seen in the specimens. Some of the crystals were evidently derived from hornblende and still retain their original crystal forms, occurring in a minute aggregate.

Biotite is a negligible component. The writer has seen it only in the hypersthene-hornblende-andesite from the eastern frank of Shabô-zan. The mineral in this specimen has a beautiful yellowish-brown colour, and forms irregular patches surrounded by a granular aggregate of the brown hornblende.

Apatite is accessorily present, and it takes a stout prismatic or granular form, the largest crystal being 0.35 mm. in length. Magnetite and haematite are always very common minerals, and both are not infrequently found together in a rectangular or granular form. Haematite seems to have been altered from magnetite, aud it is particularly abundant in the intensely oxidized andesite. They are not only scattered over in the groundmass, but are also associated with hypersthene and hornblende. Garnet is usually absent.

As will be inferred from the microscopical investigation, the order of crystallization of various composition minerals is overlapped to some extent. Among them, the phenocrystic plagioclase seems to have been formed in the earliest stage of crystallization and was probably succeeded by magnetite and apatite. It is remarkable that the plagioclase phenocryst is, in its nucleus, quite free of the inclosures of these two minerals. They are, however, occasionally included in hornblende and hypersthene crystals, suggesting that some of them were already crystallized before the ferro-magnesian minerals. Hornblende is generally earlier than hypersthene, whereas the crystallization of biotite took place before hornblende. Haematite is the final oxidation product chiefly derived from magnetite.

MODE OF OCCURRENCE AND GENERAL FEATURES OF COGNATE INCLUSIONS

The inclusions under consideration are generally found as orbicular or ellipsoidal masses ranging from one centimeter to thirty centimeters in longer diameter. They are either enclosed in gray andesite or its brown varieties, showing mostly an abrupt transition to the matrix and also an irregular contact surface. A banded structure is sometimes seen along the border where the rock frequently indicates very fine granular texture.

Such inclusions generally have a characteristic appearance somewhat resembling a dioritic or gabbroid rock with a dark colour due to the abundance of hornblende crystals. They are commonly very hard and compact rocks, but the masses are occasionally so loose and brittle that they can be easily crushed between fingers.

There are some textural variations, from coarse to fine, even within the same specimen. The coarsest variety is almost composed of large hornblende crystals, two centimeters or thereabouts in the maximum length, and an intersertal plagioclase, whereas the finest one is quite similar to the aplitic rock in its texture. Furthermore, the mialoritic cavities are often seen in the coarser varieties and they are incrusted by many minute crystals of plagioclase and hornblende. The writer has collected some of them at the small quarry which is on the southern slope of the hill.

As can be observed at several places, the inclusions are always sporadically distributed here and there without any regular arrangement. In this case, they are also characterized by the occurrence of various alteration stages due to reheating to which the inclusion-bearing andesites were equally subjected.

PETROGRAPHY OF COGNATE INCLUSIONS

Not only megascopically but also microscopically the cognate inclusions have a characteristic feature, being quite different from the surrounding rocks.

It is composed of basic plagiocalse, hornblende, hypersthene, iron ores, augite, and apatite (Fig. 2, Pl. II [XXVII]). These minerals are found as a granular aggregate resembling some basic plutonic rock.

Plagioclase ranges from basic labradorite to acidic anorthite, having the following indices of refraction on (010), viz., n_1=1.560—1.576, n_2=1.565—1.582. Hence, the composition corresponds to $Ab_{38}An_{62}$—

Ab_8An_{92}. The extinction angle is 20°–42° on (010). The zonal structure, if present, is not so remarkable as is shown by the plagioclase phenocryst of andesite. In such a case, the basicity commonly increases toward the interior, but the more acidic or more basic parts are sometimes alternately arranged. It generally twins after the carlsbad or albite law. The pericline type is also to be seen.

Hornblende is one of the important ingredients. It usually takes a a prismatic habit, the largest crystal being 2 cm. in length. The optical properties of basaltic or brown hornblendes of this cognate inclusion are similar to those in the mother-rock, and there are various transition stages of alteration between them. The basaltic hornblende is strongly pleochroic: X=light yellow, Y=brownish-yellow, Z=dark yellowish-brown. It is much different from the brown variety which has a very characteristic pleochroism: viz., X=amber yellow, Y=yellowish-brown, Z=reddish-brown. The absorption is $Z>Y>X$ in both cases. The extinction angle of the basaltic hornblende, $Z\wedge c$, is 2°–10°, while in the brown hornblende $Z\wedge c=0°–2°$. These hornblendes are optically negative. The indices of refraction of the brown hornblende in the type specimen are $\alpha=1.685$, $\beta=1.711$, $\gamma=1.731$. Birefringence, $\gamma-\alpha=0.046$, $2V=82°20'$. The basaltic hornblende, on the other hand, shows a decrease in the indices of refraction and birefringence, whereas the extinction-angle increases up to 10°. The plane of the optic axis is parallel to (010), and the acute bisectrix coincides with X. Some of the crystals twin on (100). They frequently contain such inclusions as plagioclase, hypersthene, magnetite, apatite, and biotite. Plagioclase here is mostly found as patches and is a prominent inclusion in these hornblendes. Moreover, the hornblende is generally subjected to a magmatic resorption, and the crystals are partly or wholly changed into the minute aggregates of magnetite, haematite, hypersthene or augite, etc. (Fig. 1, Pl. II [XXVII]). The brown hornblende is undoubtedly a secondary product from the basaltic variety. When the basaltic hornblende is slightly altered, it acquires a little different colour, a reddish-brown shade, showing more or less stronger pleochroism than before: viz., X=light brownish-yellow, Y=dark yellowish-brown, Z=dark brown with a reddish shade. Sometimes it exhibits different stages of alteration even in the same crystal: in this case a less-changed core of somewhat mottled colour is to be seen in the thin section. The alteration usually begins from the outer side and gradually proceeds into the interior.

Y. DEGUCHI[1] formerly reported the occurrence of barkevikite in the lavas of Shichisei-zan, but it does not seem to be different from the brown hornblende in the andesite and its cognate inclusions from Shabô-zan. The brown hornblende under consideration is distinguishable from barkevikite in its optical properties and chemical composition.

Hypersthene is sometimes found in a considerable amount, but it is often negligible or absolutely absent. The crystal is mostly subhedral or anhedral, some of it including minute patches of hornblende (Fig. 2, Pl. II [XXVII]) together with granular apatite and magnetite. Hence, hypersthene was probably formed later than hornblende. The largest crystal is 2.2 mm. x 0.8 mm. in size. Its optical properties are quite similar to those of hypersthene in andesite. As will be observed in the thin sections, hypersthene is a more stable mineral than hornblende, but it finally begins to segregate haematite along margins, cracks, and cleavages in the later stage of the alteration. Hypersthene under such a condition shows much stronger pleochroism.

Biotite is usually associated with hornblende in which it is often included as patches without any regular arrangement (Fig. 3, Pl. II [XXVII]). It has a tabular habit characterized by the distinct cleavage parallel to the base. There are two varieties having a conspicuous difference in pleochroism. One of them is a brown biotite, while the other belongs to a common type. The brown biotite is undoubtedly derived from the common one, showing a gradual transition into one another in some specimens. It is strikingly pleochroic from amber yellow (X) to bright reddish-brown with a yellowish shade (Y or Z). The absorption is $Y=Z>X$ and is sometimes variable along the basal cleavage. The index of refraction is $N_m=1.722$, and the birefringence is very high. The optic angle is nearly zero, and it is optically negative. The common biotite indicates, however, the following pleochroic scheme, viz., X=light

---

1) Y. DEGUCHI:—Geologicol Report on the Daiton Volcanoes. (Japanese.) p. 28.

yellow, Y=Z=dark yellowish-brown, and its index of refraction is $N_m=1.658$. The indices of refraction and birefringence are slightly lower than those of the brown biotite. This ferro-magnesian mineral is abundantly present in some specimens, but it is absolutely absent in other cases.

Augite is accessory in almost all specimens. Apatite is occasionally present in a minor quantity, taking a prismatic or granular form. The crystal is 0.3 mm. in the maximum length and is the combination of prism and pyramid. Magnetite and ilmenite are very common minerals in all thin sections, while haematite is exceedingly abundant in the highly oxidized rock. Haematite here is also undoubtedly a secondary product from magnetite or ilmenite. When the iron ores are associated with hornblende, hypersthene, and biotite, they are mostly found as inclusions or narrow rims surrounding the crystals of these ferro-magnesian minerals.

The order of crystallization of various composition minerals will be inferred from the result of microscopical investigations. In all cases, apatite is the earliest mineral and is succeeded by magnetite and ilmenite. As is shown in many thin sections, the earliest formation of magnetite or ilmenite probably took place before plagioclase, but some of them are undoubtedly later than hornblende or hypesthene. Plagioclase was sometimes crystallized out in several stages, and it is mostly earlier than biotite or hornblende. Biotite is often included by hornblende, suggesting that the former was formed prior to the latter; most of hypersthene are the final product among these ferro-magnesian minerals. Brown hornblende, brown biotite, and haematite are, on the other hand, the oxidized modifications of earlier corresponding minerals.

CHEMICAL CHARACTERS OF COGNATE INCLUSIONS

A chemical investigation of cognate inclusions has recently been carried out by H. Iinuma on the type specimens from the eastern slope of Shabô-zan. According to his study these specimens are characterized by the abundance of ferric oxide compared with a small percentage of ferrous oxide. The amount of ferrous oxide is exceedingly low in the specimen (No. II), in which it is less than one percent. Such an abnormality is undoubtedly due to the presence of brown hornblende, brown biotite, and haematite, as is shown in the mother-rocks, viz., hypersthene-hornblende-andesite or two pyroxene-hornblende-andesite. The similar tendency can also be seen between basaltic hornblende and its brown variety.[1]

The results of the chemical analyses of these cognate inclusions are as follows:

	(I)	(II)
SiO_2	47.57	44.73
Al_2O_3	17.63	19.52
Fe_2O_3	10.67	13.18
FeO	2.59	0.99
MgO	4.86	6.06
CaO	10.00	10.51
Na_2O	3.34	2.50
K_2O	1.33	0.97
H_2O	1.84	0.81
TiO_2	0.71	1.09
P_2O_5	0.12	0.10
Total	100.66	100.46

In this table the molecular proportion of Al_2O_3 is superior to that of Na_2O+K_2O in each rock, the ratio of Al_2O_3 to Na_2O+K_2O being 2.45 (I) and 3.67 (II). These two ratios are greater than 1.5 specified by T. OGURA[2] to be a boundary between calc-alkaline and alkaline rocks. Both specimens (I and II) have the ratios corresponding respectively to those of the typical diorite or gabbro in his classification.

In the preceeding table, the specimen (No. I) contains basaltic hornblende, common biotite, and hypersthene with a minor amount of brown hornblende and haematite, while the specimen (No. II) is rich in brown hornblende, brown biotite, and haematite without any trace of basaltic hornblende. From these results the following normative minerals and ratios are calculated:

---

[1] T. ICHIMURA:—Notes on Brown Hornblende and Biotite from Shabô-zan of the Daiton Volcanoes, Japan, Min. Mag., Vol. XXII, 1931, p. 564.

[2] T. OGURA:—Contact-metamorphism by Syenite-gneiss in the Lao-tieh-shan District near Ryojun, South Manchuria, Mem. Ryojun Coll. Eng., Vol. V, No. 3, 1932; p. 179.

	(I)	(II)
Orthoclase	7.79	5.57
Albite	29.36	22.03
Anorthite	28.37	38.66
Diopside	15.81	9.96
Hypersthene	0.10	2.41
Olivine	3.24	5.63
Magnetite	6.25	—
Ilmenite...	1.37	2.13
Haematite	6.38	13.26
Apatite	0.31	0.31
Total	98.98	99.95

	(I)	(II)
$\frac{\text{Sal.}}{\text{Fem.}}$	1.96 (Class II)	1.97 (Class II)
$\frac{Q}{F}$	0 (Order 5)	0 (Order 5)
$\frac{Na_2O + K_2O'}{CaO'}$	0.69 (Rang 3)	0.37 (Rang 4)
$\frac{K_2O'}{Na_2O'}$	0.25 (Subrang 4)	0.24 (Subrang 4)

It is also interesting to compare the chemical compositions of the cognate inclusions with those of the andesite lavas in the following table. The andesites were collected by T. KÔNO from the northern flank and summit of Shabô-zan, and they are the mother-rocks of the cognate inclusions under consideration. As can be seen in the results of chemical analyses (1 and 2), the cognate inclusions here are lower in silica but higher in lime, magnesia, and iron than andesites, suggesting that they are more basic than their mother-rocks. The difference between both types of rocks is more evidently shown in the proportions of the normative minerals. There are thus a remarkable decrease of salic minerals with a proportional increase of femic components in the cognate inclusions. Furthermore, the inclusions similarly indicate an increase of basicity in in the thin sections where the basic plagioclases and mafic minerals are more abundant than those of the surrounding rocks.

	(1)	(2)
SiO_2	59.30	58.39
Al_2O_3	18.05	17.59
Fe_2O_3	4.85	6.15
FeO	1.89	1.11
MgO	2.18	2.40
CaO	7.38	6.96
Na_2O	2.29	1.90
K_2O	2.64	3.51
Ig. loss	0.79	1.19
TiO_2	1.36	1.24
P_2O_5	0.08	0.15
MnO	0.10	0.14
Total	100.91	100.73

Norm

	(1)	(2)
Quartz	18.13	16.58
Orthoclase	15.58	20.76
Albite	19.35	16.10
Anorthite	31.21	20.06
Diopside...	3.81	4.24
Hypersthene	3.66	4.06
Magnetite	2.48	0.46
Ilmenite...	2.58	2.36
Haematite	3.15	5.83
Apatite	0.19	0.34
Total	100.14	99.74

Ratios

	(1)	(2)
$\frac{\text{Sal.}}{\text{Fem.}}$	5.35 (Class II)	4.79 (Class II)
$\frac{Q}{F}$	0.27 (Order 4)	0.25 (Order 4)
$\frac{K_2O' + Na_2O'}{CaO'}$	0.58 (Rang 4)	0.65 (Rang 3)
$\frac{K_2O'}{Na_2O'}$	0.76 (Subrang 3)	1.21 (Subrang 3)

(1) Gray andesite from the northern flank of Shabô zan.

(2) Reddish andesite from the summit of Shabô zan. Analyst, T. Kôno[1]

As will be understood from the results of these chemical analyses, Al_2O_3, CaO, MgO, FeO, Fe_2O_3, and Na_2O in cognate inclusions and their mother-rocks vary sympathetically with each other, but they are in an antipathic relation to K_2O and TiO_2. Such tendencies may suggest some approximate course of the magmatic evolution.

The noritic inclusions from Sakura-jima[2] are also more basic than their mother-rocks. They are, however, somewhat different from those of Shabô-zan, both minerallogically and chemically.

THE FORMATION OF COGNATE INCLUSIONS.

Although some angular or subangular pieces of highly metamorphosed sediments are found in the andesite lavas of Shabô-zan, they are quite different from the inclusions under consideration, both megascopically and microscopically. Such accidental inclusions are always represented by schistose rocks recrystallized probably from the Tertiary or still older sandstone, consisting of quartz, plagioclase, haematite, hypersthene, biotite, cordierite, etc. They have a gray or dark gray colour with a purplish shade due to the presence of abundant haematite. In some specimens, a narrow contamination zone is also to be seen along the contact part.

---

[1] T. Kôno:—Geochemical Studies on the Daiton Volcanoes, Rep. Dep. Ind., Government Research Institute, Formosa, No. 69, 1931, pp. 11, 13.

[2] K. Yamaguchi:—On the Orbicular Noritic Inclusions in the Lavas from Sakura jima, Jour. Geol. Soc. Tôkyô, Vol. XXXIV, 1927, pp. 399, 404.

The cognate inclusions are, on the other hand, very characteristic rocks with a granular texture somewhat resembling plutonic types, and their mineral composition shows a close similarity to that of the mother-rock except the occurrence of such basic plagioclases as bytownite or anorthite. The inclusions are thus likely to have an intimate genetical connection to hypersthene-hornblende-andesite or two pyroxene-hornblende-andesite, as is indicated by the gabbroid or noritic inclusions in the andesitic lavas from Sakura-jima.1)

They were probably formed in the beginning of crystallization of magma in which many floating crystal adhered together to build up rounded or ellipsoidal masses.

As will be understood from the microscopical investigations, the plagioclases of the coarse-grained varieties are mostly free of the zoning, and its absence suggests that they were crystallized out in the moderate rate of cooling. Under such a condition, the equilibrium can constantly be maintained between crystals and liquid, the continual readjustment being carried on almost completely. Zoned plagioclases are, however, abundantly found in the fine-grained inclusions. Hence, it seems that the inclusions were continuously formed in a different physico-chemical condition of magma, and they are more acidic in the later stage.

The formation of some inclusions is undoubtedly overlapped with the earliest crystallization of phenocrystic plagioclase of the mother-rocks, which is always characterized by the presence of more complicate zoning due to the continuous reaction of the residual liquid in rather rapid rate of cooling.

The crystallization of hornblende took place a little later than the earliest stage of plagioclases both in inclusions and their mother-rocks. Most of this mineral became a confused-aggregate of magnetite, hypersthene, augite, etc. along the periphery or cracks, as a result of the reaction of the liquid, which suggests that the formation of the cognate inclusions had not still been completed up to this time. The growth of

---

1) B. Kotô :- The Great Eruption of Sakura-jima in 1914, Jour. Coll. Imp. Univ. Sci. Tôkyô, Vol. XXXVIII, Art. 3, 1916, pp. 190-196. K. Yamaguchi : op. cit., p. 494.

hornblende was, therefore, much interrupted by the plagioclase already consolidated in the cognate inclusions, and it was sealed up between them without taking any regular form.

The phenocrystic hornblende of andesites often takes a very good crystal form which was more severely subjected to the magmatic resorption than that of the inclusions, some of the crystals entirely passing into an aggregate of magnetite and pyroxene. On account of the successive change of the magmatic condition, the complicate zoning of phenocrystic plagioclases and the magmatic resorption of hornblende crystals were furthermore extended even after the final formation of inclusions. Hence, there are found some traces of alteration due to the reaction along the contact part of all cognate inclusions.

In the coarse-grained inclusions, the interstices of large crystals are filled up by the mesostasis exactly similar to the groundmass. This substance is the last consolidation product of the residual liquid which creeped into the interstices of the crystals. Judging from the fact that the inclusions are a granular aggregate of basic plagioclase, hypersthene, biotite, augite, magnetite, ilmenite, haematite, etc., the specific gravity might have been greater than the residual liquid. They are, therefore, expected to fall down to the depth, if the magma were cooled very slowly at that time. The occurrence of the inclusions is, however, rather negligible compared with the total amount of the magma. Moreover, the cooling condition of magma seems to have passed at a more rapid rate during their consolidation, and the subsidence of such masses might be restricted to some extent. When they were still suspended in the magma, they happened to be brought up to the surface by the eruption.

ALTERATION OF COGNATE INCLUSIONS

It has already been shown that there are two different types of hornblende-bearing andesites at the Daiton volcanoes, and they have a gray or reddish colour, both varieties exhibiting a gradual transition into one another.

The best exposure is found at Shabô-zan and its vicinity where hypersthene-hornblende-andesite or two pyroxene-hornblende-andesite contain some cognate inclusions. The reddish andesite of this locality was undoubtedly derived from the gray variety.

A similar stage of alteration is also observed in many specimens of cognate inclusions collected by the writer from the same locality. Most of these specimens are more or less subjected to oxidation, the extremely changed ones being of a somewhat purplish or reddish shade.

The striking alteration of the cognate inclusions is well shown by the results of the chemical analyses carried out by IINUMA. According to his investigation, a characteristic feature is the decrease of ferrous oxide and the increase of ferric oxide. It is particularly remarkable in the highly altered specimens. In an extreme case, ferrous oxide is almost absent, and such abnormality seems to be due to the presence of brown hornblende, brown biotite, haematite, etc.

Under the microscope, they are always characterized by the conspicuous decrease of basaltic hornblende or common biotite, and the correspording increase of brown hornblende or brown biotite. It is noticeable that basaltic hornblende and common biotite begin to be attacked along margins, cracks, and cleavages of crystals, and then they wholly pass into brown hornblende or brown biotite in association with a dusty aggregate of haematite which were mostly dervied from magnetite and ilmenite. Such varying transition stages are traceable even in one and the same hand specimen. Hypersthene remains unchanged for a while, but finally it is much affected, and segregates haematite.

So far as is known in thin sections, limonite is scarcely present, while haematite is a common mineral in much oxidized stages. Moreover, plagioclase holds a very fresh appearance even in exceedingly altered specimens. The chemical composition similarly suggests that the cognate inclusions under consideration became changed without any decomposition due to weathering.

Several years ago, S. KÔZU and his associates[1] tried some thermal experiments on the quartz-andesite from the volcano Sambé. They heated its gray variety up to 750°C and obtained a reddish type. In this case, common hornblende and meroxene mica changed into basaltic hornblende and anomitic mica. From this experimental work, KÔZU1) concluded that the reddish andesite of the volcano Sambé is probably an oxidation product due to reheating. The alteration of this andesite has some similarities to that of the andesite from Shabô-zan or elsewhere.

---

[1] S. KÔZU, B. YOSHIKI and K. KANI: Sci. Rep. Tôhoku Imp. Univ., Ser. 3, 1927, Vol. 3, p. 143.

Not only here, but also at the old crater walls or intensely heated area of the Daiton volcanoes the reddish variety of hornblende-bearing andesite is very occasionally exposed. The occurrence of this rock seems, therefore, to have some genetical connection to the successive volcanic eruptions. The distribution of the cognate inclusions rich in basaltic hornblende and common biotite is restricted only in the gray andesite. They were probably reheated together with their mother-rocks and are likely to have been transformed into the brown hornblende-bearing varieties.

SUMMARY

(1) The hypersthene-hornblende-andesite or two pyroxene-hornblende-andesite contains many inclusions with an orbicular or ellipsoidal form. They always have a granular texture somewhat resembling diorite or gabbro.

(2) Mostly the inclusions have a sharp border against their mother-rocks, although there is sometimes a tendency to have a fine granular texture along the contact part.

(3) Such inclusions are sporadically distributed in andesite lavas without any regular arrangement.

(4) There are two types of these rocks, the one being characterized by the occurrence of basaltic hornblende or common biotite, whereas the other contains brown hornblende or brown biotite. The former was undoubtedly derived from the latter, and they have varying transition stages between them.

(5) It is noticeable that plagioclases of cognate inclusions are repre-

---

1) S. KÔZU—An Interesting Example of the Mode of Occurrence of Basaltic Hornblende Associated with Anomitic Biotite in Quartz-andesite which forms the Volcano Sambé, Japan, Proc. 4th Pacific Science Congress, Java, 1929, Vol. 2, B, p. 721.

sented by more basic varieties than those of the mother-rocks. Moreover, the zoning of plagioclases is nearly absent in most inclusions except fine-grained varieties.

(6) As will be understood from the results of chemical analyses, the cognate inclusions of reddish andesites are abnormally high in ferric oxide, but remarkably low in ferrous oxide.

(7) Mineralogically, and also chemically, it is obvious that the brown hornblende or brown biotite-bearing varieties were not formed by weathering, but they are the oxidized products due to the reheating of basaltic hornblende or common biotite-bearing varieties.

(8) Many evidences suggest that the inclusions were likely to have been formed in the beginning of crystallization of magma from which hornblende-bearing andesites were derived. When these masses were floating in the magma, they happened to be brought up to the surface by the eruption and were sealed into the andesitic lavas.

PLATE I [XXVI]

Explanation of Plate I [XXVI]

Fig. 1. Hypersthene-hornblende-andesite from the eastern slope of Shabô-zan. ×60.

H = Brown hornblende, Hy = Hypersthene, M = Magnetite and haematite, P = Plagioclase.

Plagioclase ranges from acidic labradorite to basic labradorite. Some of these are characterized by the presence of a turbid zone. Haematite is abundantly found in the groundmass.

Fig. 2. Cognate inclusion in the hypersthene-hornblende-andesite from the eastern slope of Shabô-zan. ×60.

H = Brown hornblende, M = Magnetite and haematite, P = Plagioclase. The plagioclase of this cognate inclusion is represented by a basic bytownite or acidic anorthite. The zonal structure and turbid zone can not be seen in these types of plagioclase. Hornblende crystals have a resorbed border which are composed of a confused aggregate of haematite, magnetite, and hypersthene.

The texture is quite different from that of the mother-rock.

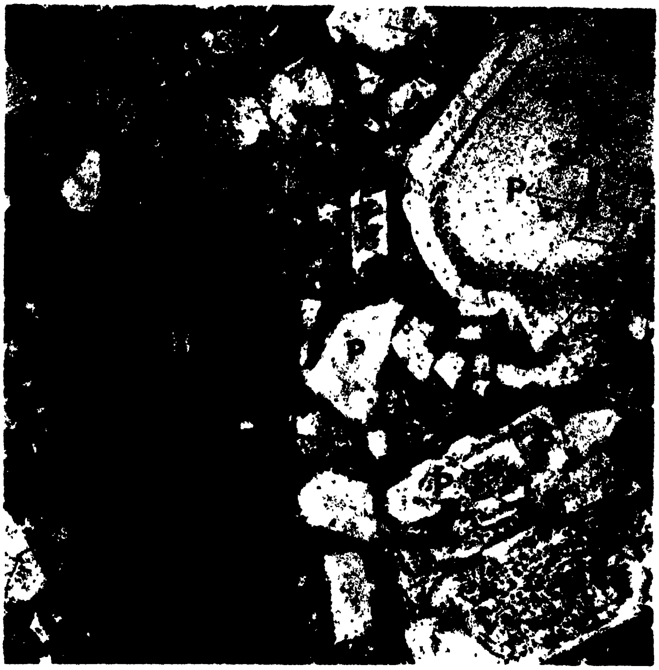


Fig. 1.

Fig. 2.

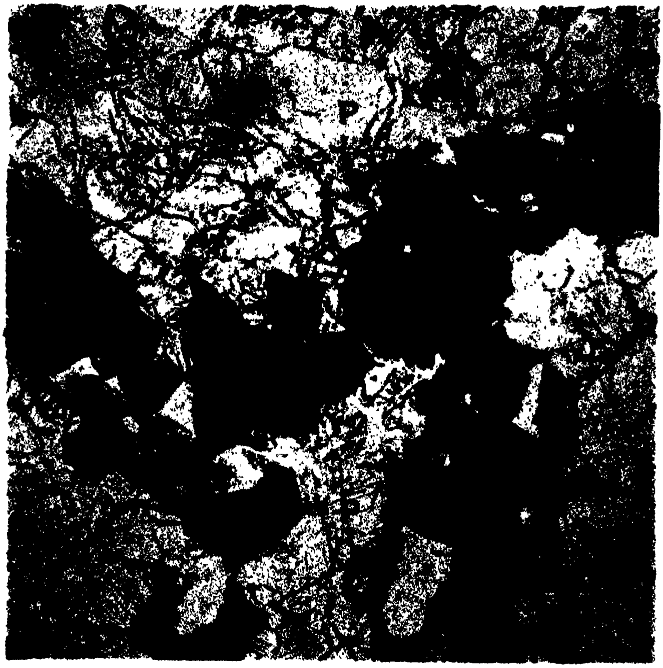


PLATE II [XXVII]

Explanation of Plate II [XXVII]

Fig. 1. Hornblende crystal passing into an aggregate of haematite, magnetite, and hypersthene. ×55.

H = Hornblende; Hy = Confused aggregates of hypersthene, haematite, and magnetite; P = Plagioclase.

Fig. 2. Hornblende crystals in hypersthene suggesting that hornblende was crystallized earlier than hypersthene. ×55.

H = Hornblende; Hy = Hypersthene; P = Plagioclase.

Fig. 3. Biotite flakes included by hornblende. ×55.

B = Brown biotite; H = Brown hornblende; M = Magnetite or haematite; P = Plagioclase.

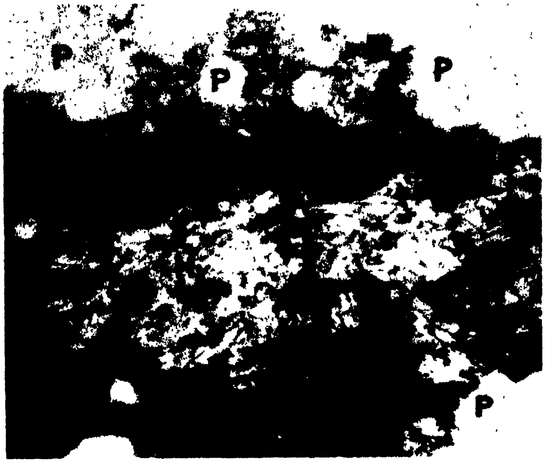


Fig. 1.

Fig. 2.

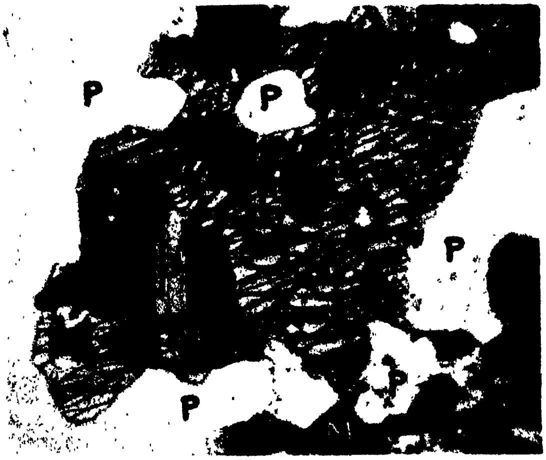


Fig. 3.

臺北帝國大學理農學部紀要

第七卷　第一號

昭和七年十月

MEMOIRS
OF THE
FACULTY OF SCIENCE
AND
AGRICULTURE

TAIHOKU IMPERIAL UNIVERSITY

Vol. VII. No. 1.-2

OCTOBER, 1932

HIRASAKA, Kyosuke: The Occurrence of Dugong in Formosa.
KAWAGUTI, Siro: Revision of Parker's Method of the Determination of Carbon-Dioxide Production.
KAWAGUTI, Siro: On the Physiology of Land Planarians.
I. Phototaxis, with a Note on the Significance of the Eye Spots.
II. Galvanotaxis.
III. The Problems of Desiccation.
KAWAGUTI, Siro: Studies on the Disintegration of *Branchiura sp.* by Methylene Blue.
I. The Effect of Temperature and Thermal Destruction.

PUBLISHED
BY THE
TAIHOKU IMPERIAL UNIVERSITY
FORMOSA, JAPAN

PUBLICATION COMMITTEE

Professor **Kintaro Oshima,** Dean of the Faculty (*ex officio*)
Professor **Ichirô Hayasaka**
Professor **Kichimatsu Matsuno**
Professor **Tokuichi Shiraki**
Professor **Tyôzaburô Tanaka**

The Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University, is published occasionally by the University and is distributed to institutions of learning throughout the world for exchange. Separate series will be sent to independent research institutions, and complete series to the central libraries of universities and major institutions. Copies of the Memoirs may also be obtained from Maruzen Company Ltd., Tôkyô, Japan.

All communications regarding the Memoirs should be addressed to the Dean of the Faculty.

臺北帝國大學理農學部紀要

第七卷

昭和七年—昭和九年

MEMOIRS
OF THE
FACULTY OF SCIENCE
AND
AGRICULTURE
TAIHOKU IMPERIAL UNIVERSITY

Volume VII.

1932-1934

TAIHOKU IMPERIAL UNIVERSITY
FORMOSA, JAPAN

CONTENTS

Page.

Harada, Isokiti:—Zur Biologie des Zooplanktons im Zitugetutan (See Candidius). (Studien über die Süsswasser-Fauna Formosas II.)… 71

Hirasaka, K.:—The Occurrence of Dugong in Formosa. … … … 1

Kawaguti, Sirô:—Revision of **Parker**'s Method of the Determination of Carbon-Dioxide Production. … … … … … … … … … 5

Kawaguti, Sirô:—On the Physiology of Land Planarians, I. Phototaxis, with a Note on the Significance of the Eye Spots. … … 15

Kawaguti, Sirô:—On the Physiology of Land Planarians, II. Galvanotaxis. … … … … … … … … … … … … … … … 29

Kawaguti, Sirô:—On the Physiology of Land Planarians, III. The Problems of Desiccation. … … … … … … … … … … 39

Kawaguti, Sirô:—Studies on the Disintegration of *Branchiura* sp. by Methylene Blue, I. The Effect of Temperature and Thermal Destruction.… … … … … … … … … … … … … … 57

Kawaguti, Sirô:—Studies on the Disintegration of *Branchiura* sp. by Methylene Blue. II. Respiratory Quotient and Respiration of Acidified Tissue. … … … … … … … … … … … … 141

Kawaguti, Sirô:—Effect of Oxidation-Reduction Potential Indicators on the Oxygen Consumption and the Respiratory Quotient of *Branchiura sowerbyi*. … … … … … … … … … … … 147

ERRATA

	Line	Read	For
	30	Pᴀʀᴋᴇʀ's	Parker's
Table 2,	Col. 2		
	2	100 m.c.	200 m c.
	3	forms	froms
	20	milliamperes	milliampers
	13	salamander	*Salamander*
	4	several	seveɹal
	29	range	rônge

THE OCCURRENCE OF DUGONG IN FORMOSA

(With 1 plate)

Kyosuke HIRASAKA

(Accepted for publication September 8th, 1932)

I have been told about the capture of a queer marine mammal in the southern part of this island in the early spring of 1931.

The story, as told by the fishermen, is as follows: The animal was caught near the beach of Tai-jyu-bo, a village on the west coast of Formosa (21°56′40″ N., 120°45′30″ E.) at 10 a.m. on January 18, a cold, windy day. Its body as measured was 3 m. long, .7 m. high, 2 m. in circumference and weighed nearly 400 pounds. The surface of the skin was like that of the water-buffalo with a few scattered bristles. The nostrils were on the upper surface of the snout. A pair of tusks (incisors) were on the tip of its upper jaw; they were 20 cm. long, cylindrical, but were truncated obliquely at the end. Small eyes and ear holes were recognised. The forelimbs were like the flippers of the hawk-bill, without nails. No hind-limbs existed and the posterior end of the body was flattened to a bifurcated tail, its pointed tips nearly .6 m. apart. The ventral side of the body was provided with a pair of nipples at the breast and a penis, nearly .6 m. long, on the abdomen. All these data are by no means exact, as they were told only from memory.

The flesh of this animal was palatable, similar to pork in taste and without any particular odor. Inside the stomach were found quantities of marine algae and crabs.

It is said that there are two or more in the vicinity of this spot but they are very rarely seen because of their extreme shyness.

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa Japan, Vol. VII., No. 1. October, 1932.]

Afterward I fortunately got the skull, with the lower jaw, of the same animal. This was found in the garbage by an official of that district and was kindly offered to me for investigation.

The skull (Fig. 1, Pl. I.) was mutilated in taking away the incisors and molars. Nearly three-fourths of the anterior of the premaxilar was cut off along with the incisors and the greater part of the maxilar, palatine, and vomer were lost. The skull measured as follows: the greatest length, 295 mm. (+ x for the unmeasured broken portion); zygomatic breadth, 205 mm.; the breadth between the orbito-temporal fossae, 85 mm.; its height, 147 mm.

The mandible (Fig. 2, Pl. I.) is rather complete, except for the broken left molar sockets and the right condylus mandibulae. On the symphysial end there are four pairs of alveolus for degenerated teeth, which are covered with rugosities of thick horny membrane in life. The sockets for three molars are seen in the middle of the right half. The length of the molar series is 70 mm. The margin of the third socket is not round but is oblong, with vertical ridges on both sides and looks like two cylindrical columns fused on the sides.

There is no doubt that this is a dugong, *Halicore dugong* (ERXL.) and the first one scientifically ascertained and recorded from Formosa.

Another report of the capture of a young male in April and an adult male in June 1931 came from Haikau, a port near Koshun. These were probably dugongs as the place is not far from that of the former capture and the topography is quite the same, being a sandy beach interwoven with raised coral-reefs.

Even if there is no information on the subject, we doubt if there is a wide distribution of this mammal along the eastern coast of Formosa, according to the traditions about this sea-shore monster among the aborigines who live on this lonely coast.

Furthermore, among Formosan fishermen there are several stories about furred animals from the sea, occasionally in a different season of the year, but almost all of them seem to me to be strayed wanderers of the Pinnipedia. For example, recently a common seal *Phoca vitulina*, was captured in Tansui in May, 1932 and is now kept alive in the pond of the Taihoku Zoological garden.

Now let us consider the distribution of the dugong. They were fairly abundant in the water surrounding the Ryukiu Islands and Amami-oshima many decades before and were hunted eagerly for flesh and oil. This hunting was carried on regularly once a year by feudal lords for tribute in Aragusuku Island, near Ishigakishima (Matsubara, 1881[1]; Kuroiwa, 1894[2].). However, the present condition of these animals in these islands is rather deplorable, as these Sirenians are on the point of extinction and are extremely rare.

I have heard from an old fisherman that once one was caught in a large trap seine for yellow-tails, off Abratsu, a port on the eastern shore of Kyushu about thirty years ago. Perhaps this may be the most northern limit of its distribution.

On the other hand, it is known in Mindro, Philippine Islands (Hollister, 1912[3]). Therefore it is rather strange that there has been no record yet from Formosa as it is quite probable that this animal should be found in this island, which is situated between the Philippines and Ryukiu Islands and is washed by the same current of Kuro-shiwo (the Japan current).

Before this short note is concluded, I wish to express my thanks for the kind assistance rendered by Prof. B. Aoki of this University, and Messers Y. Yogi and S. Yasaka, the Fishery Experts of the Formosan Government.

June 8, 1932,
Taipeh, Formosa.

---

1) Matsubara, S. On the Dugong of Japan. (In Japanese.) Dob. Zas. **1**; p. 93-96.

2) Kuroiwa, T. The hunting-ground of Dugong. (In Japanese.) Dob. Zas. **7**; p. 395.

3) Hollister, N. A list of the mammals of the Philippine Islands, exclusive of the Cetacea. Philipp. J. Sci. Manila. D. **7**; pp. 1-64.

Explanation of Plate I.

The skeleton of *Halicore dugong* (Erxleben) caught in Formosa.

Figure 1. The dorsal view of the skull. (Not complete.)

Figure 2. The dorsal view of the lower jaw. (Molars taken off.)

(Details, with measurements, in the text.)

Fig. 1.

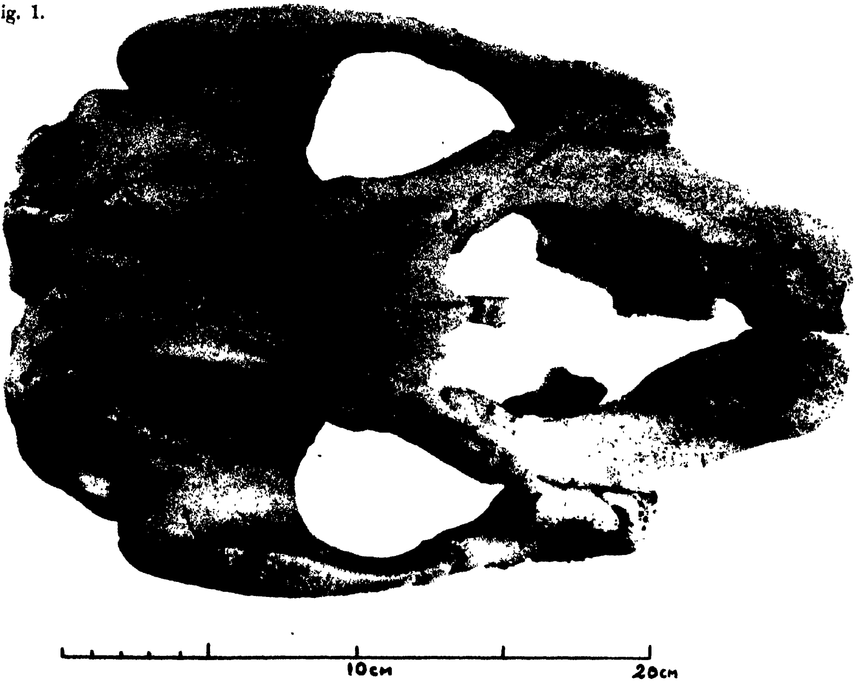
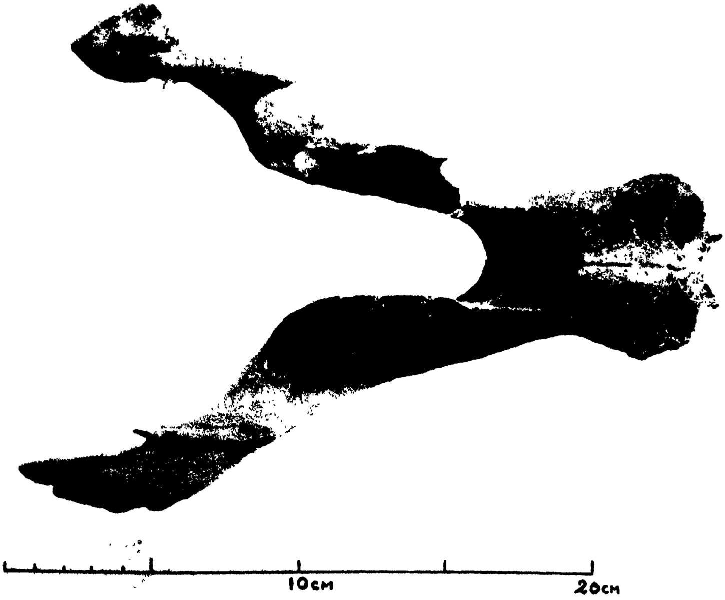


Fig. 2.



K. Hirasaka: The Occurrence of Dugong in Formosa.

REVISION OF PARKER'S METHOD OF THE DETERMINATION OF CARBON-DIOXIDE PRODUCTION

Siro KAWAGUTI

(Accepted for publication September 8th, 1932)

I(1)

PARKER's colorimetric quantitative determination of the production of carbon dioxide by organisms has been used frequently by physiologists ever since his first paper (1925) appeared. In 1928, he corrected his method from a theoretical point of view, but gave no reasons for his corrections. Even after its correction, the datum does not coincide with the datum which has been obtained by direct calibration in introducing a known volume of carbon dioxide, and he did not explain these discrepancies.

In my study of respiration, I intended to measure carbon dioxide by PARKER's method, and encountered a chance to find out the weak point which may probably cause these discrepancies in his method.

For the convenience of discussion, I quote several lines of RAY's paper, as PARKER used this method of calculation. (RAY, 1924, pp. 510–1) "The method is as follows;

$$\frac{[\overset{+}{H}]\ [H\overset{-}{C}O_3]}{[H_2CO_3]}=k_a \qquad (1)$$

in which k_a=the dissociation constant of H_2CO_3.

---

(1) This part has been sent to Prof. G. H. PARKER. I am very grateful for his generosity and encouragement. I also express my sincere thanks to Prof. HIRASAKA for his kindness during the preparation of this paper.

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa Japan, Vol. VII., No. 1, October, 1932.]

$$[\overset{-}{HCO_3}]=[NaHCO_3]\ \gamma \qquad (2)$$

in which γ is the dissociation constant of $NaHCO_3$.

$$[H_2CO_3]=[CO_2]\ k \qquad (3)$$

in which k is the absorption coefficient of CO_2.
From 1, 2 and 3

$$\frac{[\overset{+}{H}]\ [NaHCO_3]}{[CO_2]\ k}=\frac{k_a}{\gamma} \qquad (4)$$

or

$$\frac{[\overset{+}{H}]}{[CO_2]}=\frac{k_a \times k}{\gamma\ [NaHCO_3]} \qquad (5)^{(2)}$$

Equation (5) was used to calculate the concentration of CO_2 at pH 7.78 and 7.36. The value of k_a used was the one given by Kendall, 3.5×10^{-7}; and the value of γ, since the concentration of the $NaHCO_3$ was M/10,000, was taken as 1. The absorption coefficient of CO_2 was also taken as 1.

For pH 7.78 ($[\overset{+}{H}]=0.167 \times 10^{-7}$)

$$\frac{0.167 \times 10^{-7}}{[CO_2]}=\frac{3.5 \times 10^{-7}}{0.0000841} \qquad (6)$$

$$[CO_2]=0.004\text{ mg. in }10\text{ cc.} \qquad (7)$$

For pH 7.36 ($[\overset{+}{H}]=0.44 \times 10^{-7}$)

$$\frac{0.44 \times 10^{-7}}{[CO_2]}=\frac{3.5 \times 10^{-7}}{0.0000841} \qquad (8)$$

$$[CO_2]=0.0106\text{ mg. in }10\text{ cc.} \qquad (9)$$

Hence

0.0106 − 0.004 = 0.0066 mg. CO_2 to change 10 cc. from pH 7.78 to 7.36."

In equation 6, the value of the denominator of the fraction on the right hand side apparently shows the total weight of the $NaHCO_3$ in 10 cc. of 1/10000 M solution. By this treatment of equation 5, he obtained the $[CO_2]$ in 10 cc. of $NaHCO_3$ solution, as has been given in equations 7 and 9. I believe that $[CO_2]$ and $[NaHCO_3]$ represent the molar concentrations of each substance, as shown in equations 2 and 3, and the same conditions may hold also in equation 5. Therefore it seems to me that to put the total weight in 10 cc. 1/10000 M $NaHCO_3$ in equation 5, and to calculate the total weight of the CO_2 in the solution, as has been done by him in equations 6 and 8, may be a mistake.

---

(2) Apparent misprints in this equation have been corrected and additional denotations have been given to equations 6, 7, 8 and 9.

It may be correct to calculate the molar concentration of CO_2 by putting the molar concentration of $NaHCO_3$, then to calculate the total weight of CO_2 in 10 cc. of the solution. Then we can go on as follows, in place of equations 6 and 8;

For pH 7.78

$$\frac{0.167\times10^{-7}}{[CO_2]}=\frac{3.5\times10^{-7}}{10^{-4}}$$

$$[CO_2]=4.77\times10^{-6}\text{ mol.}$$

Then the total weight of CO_2 in 10 cc. of the solution may be

$$=44\times4.77\times10^{-6}\times10^{-2}\text{ gm.}$$

$$=2.10\times10^{-6}\text{ gm.}$$

In the same manner, for pH 7.36,

$$[CO_2]=12.58\times10^{-6}\text{ mol,}$$

and the total weight of CO_2 in 10 cc. of the solution is

$$=5.53\times10^{-6}\text{ gm.}$$

Thus the weight of CO_2 which is necessary to change the pH from 7.78 to 7.36 is

$$(5.53-2.10)\times10^{-6}\text{ gm.}=3.43\times10^{-6}\text{ gm.}\quad(10)$$

These data correspond to about a half of RAY's data and differ greatly from the data corrected by DAVIS, who showed that it is necessary to multiply the data of Parker's method by a correction factor of from 0.619 to 0.623, depending upon the temperature.

Now my attention is turned to PARKER's second paper, in which he wrote; "Adopting Doctor Cohn's correction and calculating the carbon dioxide separately for the 5 cc. of fluid and the 37 cc. of gas in the respiratory chamber at 23°C., the total amount proved to be 0.018,18 mgm. or a little less than 66 per cent of the estimate by the earlier procedure."

From these remarks it can be understand that he considered the unequal distribution of CO_2 between the $NaHCO_3$ solution and air, that is, the absorption coefficient of CO_2 in $NaHCO_3$ (k) is not 1, as was taken by RAY. On this point he has not written.

If we assume that the absorption coefficient of carbon dioxide is k' in this case, then the following relations can be obtained,

$$1/2 \times 6.6 \times 10^{-6}\,\text{gm.} + 1/k' \times 3.7 \times 6.6 \times 10^{-6}\,\text{gm.} \\ = 18.18 \times 10^{-6}\,\text{gm.}, \qquad (11)$$

where the first term is the amount of CO_2 which changes the pH of 5 cc. of the solution of $NaHCO_3$ from 7.78 to 7.36, and the second is that of the air of the chamber, the right hand side is the data which have been calculated by PARKER, then $k' = 1.64$.

Next, my consideration was directed to the question as to what would be the results if these corrections were applied to the theoretical data. PARKER (1928) determined that the pH of $NaHCO_3$ in his apparatus can change from pH 7.78 to 7.36 by 6.86×10^{-6} gm. of CO_2.

Supposing similarly that the absorption coefficient of CO_2 is k'', the following relations may be written,

$$3.42 \times 1/2 \times 10^{-6}\,\text{gm.} + 3.7 \times 1/k'' \times 3.42 \times 10^{-6}\,\text{gm.} \\ = 6.86 \times 10^{-6}\,\text{gm.} \qquad (12)$$

then $k'' = 2.44$.

If my understanding of PARKER's correction and his actual data of the last section are correct, k' and k'' should be equal. But the calculated data are apparently unequal. I can not say here why this discrepancy is caused, because, as far as I know, there is no literature on the absorption coefficient of carbon dioxide in $NaHCO_3$. Furthermore, I used the same values for constants in equation 5 as RAY used in his paper, excepting the absorption coefficient of CO_2, (k).

II

a. Method

After consulting with Prof. G. H. PARKER on the previous part, I undertook an experiment to determine the absorption coefficient or the partition coefficient of carbon dioxide between the air and N/10000 sodium bicarbonate. The experiment is based on the fact that if the absorption coefficient .is not unity the volume of carbon dioxide which suffices to change the pH of the test medium in a certain chamber from 7.78 to 7.36 varies according to the volume of the medium. The method of calibration was almost similar to that of PARKER (1928).

As a means of measuring carbon dioxide, PARKER used a mercury thermometer cut off at the top and the gas was sucked or expelled by warming or cooling the bulb of mercury. In my calibration, however, the capillary used was cut off at both ends. A thick-walled gum tubing was connected at one end of the capillary and its free end was pinched by a Hofmann pinchcock. Another pinchcock was prepared at the middle of the gum tube. By driving in or releasing the screw of this cock the gas in the tubing was blown out or sucked in.

To measure the volume of gas, a column of mercury about 4 cm. in length was prepared in the capillary. Its movements were read by attaching a millimeter scale on the capillary tube.

The pH was measured by comparison with the standard buffered solutions of pH 7.78 and 7.36, and besides these, of each pH 0.05 beginning from pH 7.85 to pH 7.30, prepared with primary phosphate and natron, with the same concentration of phenolsulfophtalein.

The test chamber had a diameter approximately equal to the other tubes of standard buffer solutions, and it had a capacity of just 40 cc. Two openings were made in the cork stopper of the chamber, well soaked with paraffine, the one for the insertion of the capillary of carbon dioxide, the other for regulation. Although PARKER used a kaolin mixture to close such openings, these were closed by glass rods, excepting for the little time necessary for inserting or withdrawing the capillary.

The process of the test was as follows: A definite volume of N/10000 $NaHCO_3$ with phenolsulfophtalein, which had been previously prepared in a large bottle, was poured into the test chamber. The chamber was made air-tight and was shaken vigorously for five minutes. Then the pH of the medium was examined by comparing it to the standard buffered media. If the pH deviated from 7.78, air free from CO_2 was bubbled through the test medium or air containing CO_2 was diffused in, according to the deviation being acidic or alkaline, and the pH was regulated to just 7.78.

Then a certain volume of CO_2 was introduced into the test chamber through a large opening by inserting the open end of the capillary and pinching the gum tubing.

To supply the carbon dioxide gas to the capillary, the open end was placed in a glass tubing where a generous current of gas was prepared from a tank and sent through washing bottles. The end of the delivery system was open to the air in order to avoid the difference in pressure of the gas. After one or two minutes, when all the air was driven out of the system, the Hofmann pinchcock was released and the column of mercury was displaced to the another end of the capillary. Thus the desired volume of carbon dioxide could be obtained.

In this case, the mercury which closed the carbon dioxide at the free end of the capillary was not used, because the time necessary to insert the capillary in an opening of the test chamber from the CO_2 delivery system was very short, and such manipulation seems to cause no irregular results.

As soon as the pouring manipulation was over the capillary was carefully and quickly removed and both openings were closed with glass stoppers. After shaking vigorously for five minutes, the pH change of the medium was read by comparing it with the standards. The control experiment of such manipulations was done by repeating three times with about 0.02 cc. air introduced in place of the CO_2 gas and then the test chamber was well shaken, but no appreciable change of pH could be proved.

In this experiments, carbon-dioxide gas was washed with distilled water and concentrated sulfuric acid. Gas treated in such a manner, may contain more than 98% CO_2, and the difference between this and pure CO_2 may be neglected in the calibration.

The volume of the capillary was carefully calibrated with mercury. It was proved that the volume of 1 cm. of the capillary is 20.54×10^{-5} cc., to an accuracy of smaller than 1/100.

All experiments were done in a well ventilated room. The room temperature was 30.5°–32°C.

b. Results

After many trials of such manipulations, it was proved that the following amount of carbon dioxide is just sufficient to change the pH of the test medium from 7.78 to 7.36, in each relation of volumes of sodium bicarbonate and air. The data are given in Table 1. Each datum is the average value of four or five determinations.

TABLE 1

The amount of CO_2 which is necessary to change the pH of the test chamber from 7.78 to 7.36.

Volume of $NaHCO_3$ and the air in the test chamber	CO_2 just sufficient to change pH		Absorption coefficient
	in length of capillary	$\times 10^{-6}$ gm.	
5 cc. $NaHCO_3$+35 cc. Air	18.5 cm.	6.71	2.40
10 „ „ +30 „ „	21.0	7.62	2.44
15 „ „ +25 „ „	24.7	8.97	2.23
20 „ „ +20 „ „	26.5	9.62	2.46
25 „ „ +15 „ „	29.5	10.70	2.39
30 „ „ +10 „ „	31.4	11.40	3.02
35 „ „ + 5 „ „	35.0	12.70	2.38

The absorption coefficients of carbon dioxide in sodium bicarbonate were calculated in every case, as has been done in equation 12. They are given in Table 1. These data are very like in every case, excepting in the case of 30 cc. of $NaHCO_3$, and the average value was 2.47. According to Student's method, 3.02 may be omitted in this case, then the average value becomes 2.38. The datum is nearly equal to the absorption coefficient, 2.44, calculated from the actually calibrated data of PARKER (1928) and from the theoretically corrected amount of CO_2 to change the pH of the medium from 7.78 to 7.36.

In consequence, we can say that PARKER's calibration was actually correct and the absorption coefficient, which might be used by PARKER in his calculation, 1.64 (equation 11), was not correct. Although the relations between the amount of the absorption coefficient and the temperature was not examined, it seems that the temperature does not effect them greatly and this value may be applied in approximately any case without any difficulties.

Applying this data of the absorption coefficient of carbon dioxide in sodium bicarbonate, we may use PARKER's method of the determination of carbon dioxide production without any actual re-calibration of the apparatus. This re-calibration was an unavoidable procedure in the method, if the volume ratio of the test medium and the air in the test chamber was changed from his original work.

Thus the method can be used more satisfactorily than before without any of the trouble which has been entailed.

SUMMARY

1. Corrections of the calculation in PARKER's method of the determinations of the carbon dioxide output by organisms have been proposed.

2. An attempt has been made to explain the discrepancy of the actual data and the theoretical data of the method.

3. The absorption coefficient of carbon dioxide to N/10000 sodium bicarbonate was 2.38 at 31°C, and this is nearly equal to the datum obtained from PARKER's result.

4. The method may be used more satisfactorily by applying this datum of the absorption coefficient and the theoretically corrected datum

of carbon dioxide which suffices to change the pH of the N/10000 $NaHCO_3$ for a certain range.

BIBLIOGRAPHY

DAVIS, H., Physiol. Reviews 6. 559. (1925.)
PARKER, G. H., Jour. Gen. Physiol. 7. 641–669. (1925.)
PARKER, G. H., Amer. Jour. Physiol. 86. 490–504. (1928.)
RAY, G. B., Jour. Gen. Physiol. 6. 509–523. (1924.)

ON THE PHYSIOLOGY OF LAND PLANARIANS

I. Phototaxis, with a Note on the Significance of the Eye Spots

(With 5 Text-Figures)

Siro KAWAGUTI

(Accepted for publication, September 8, 1932)

CONTENTS

1. Introduction 15
2. Material and method 16
3. Preliminary experiments 17
4. Reactions to single light source 19
5. Reactions to two horizontal beams of light 21
    a. The case of equal intensity of illumination
    b. The case of different intensities of illumination
6. Note on the significance of the eye spots 23
7. Unstable positive phototaxis 26
8. Summary 26
9. Bibliography 27

1. INTRODUCTION

There are only a few works on the physiology of land planarians including the work of COLE (1907) on the phototaxis of *Bipalium kewense*

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VII, No. 1, October, 1932]

Moseley. This may be caused by the difficulties in obtaining material in mild climates but at Taihoku it is not difficult to obtain sufficient material for physiological researches. The results of COLE's experiments, that *B. kewense* reacts negatively to the light but is not sensitive, may probably come from its nature of crawling about in the twilight but *Bipalium sp.*, being strictly nocturnal is very sensitive to the light and its phototactic reaction differs from that of *B. kewense.*

2. MATERIAL AND METHOD

The material used was *Bipalium sp.*(1) collected from the University grounds. The body length of the material selected was within 8 cm. and 10 cm. when alive. Each specimen was kept in a non-alkaline glass vessel with a piece of wet filter paper. It was used within one day after collection and was kept in the dark room for at least three hours before the experiment. Although the experiments were done with freshly collected animals, it was also found that the specimens could be reared under laboratory conditions by keeping them in a large glass vessel with some grasses or wet filter paper to give a certain humidity, and by feeding them with one living *Limax* every day.

The apparatus used for observing the orientation of the animal in a horizontal light beam was essentially like that used by TALIAFERRO (1920). Two sets of horizontal beams of light were produced, the angle between them and the distances from the platform of the experiment were changed. Each beam of light was produced by a 250 watt gas-filled Matzuda lamp with concentrated filament, which was covered with a light-tight box and properly screened. A light filter of 2 cm. thickness, to avoid the thermal effect of light, was placed in front of the slit of the box, the source of light. The filter was filled with distilled water or different color solutions in the case of the experiments on color-reactions. A simple shutter was prepared between the screen and the source of light when the relations between the reaction time and the intensity of illumination were studied, so as to eliminate the unequal intensity of illumination when the current is turned on. A sheet of wet filter paper (30 × 30 cm^2.) was used as a creeping surface for the animals. It was wet with distilled water(2) and stretched on a glass plate on the horizontal platform. After each experiment the trail of the animal was recorded by following the mucus line left by the animal, and, on the other hand, searching movements in the air or on a horizontal plane were recorded in another note. The angle of orientation was measured by a graduator to half a degree. The experiments were performed in a dark room during a period from January to March, 1931. The room temperature was within 17–20°C.

---

(1) Specimens of this species were sent recently to Prof. T. KABURAKI, of Tokyo Imperial University, and it is expected, the exact name will be determined by him before long.

3. PRELIMINARY EXPERIMENTS

There are two modes of locomotion in this species, one is ciliary gliding, the other is looping with muscular contractions. The former is the normal locomotion and the latter occurs when the animal is forced to move vigorously. In the case of ciliary gliding on a horizontal plane, the animal proceeds forward in a wavy path, holding the anterior end a little above, creeping with the sole, which exists only in the median ventral line and is about 1 mm. in breadth, while any other part of the ventral surface does not contact the plane.

a) Effect of starvation: The material which has been kept in a starved condition for three days reacts irregularly to light. Even if the animal can react normally in these conditions it fatigues earlier than is normal. On the contrary if the animal is fed, it reacts in an ordinary manner even after ten days in captivity.

b) Effect of fatigue: When the experiments are done successively on the same animal its reaction often becomes very irregular. For this reason one animal is not used more than two times in succession.

c) The above-mentioned effect of fatigue may come from two different causes, one is the fatigue from muscular movement or that of the motor system, and the other is the fatigue of the photosensory reaction.

---

(2) The reason why distilled water was used is to avoid any unnoticed effect of tap water, as chemicals effect phototaxis in several animals. (Rose, 1929).

An experiment was done to ascertain this difference. One animal was exposed to about twenty minutes of continuous movement in the dark caused by several mechanical stimulations and the other one was put under a continuous exposure to a light stimulation at a distance of 150 cm. from the source of light for an equal length of time. These two animals were subjected to a light stimulation, the former reacted with apparently negative phototaxis, as is normal, but the latter did not react. These results seem to me to be caused by the existence of a constant amount of photosensory substance, as is proposed by several authors and is generally accepted. The reactions are supposed to be induced by the decomposition of this substance and this decomposed substance is resynthesized in the dark.

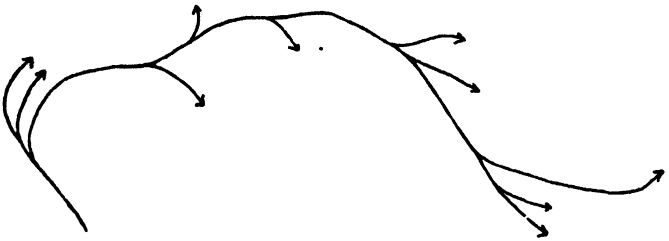


Fig. 1.

An example of the movement of a land planarian under a dark red light. Reproduced from the trace of the animal on filter paper, about $^1/_5$.

d) There are some unbalanced specimens that easily react to one particular side, right or left. For example, one animal, which has been subjected previously to one light, reacts to a second light, which is perpendicular to the first, as follows: mean turning angle when the light is given from the right hand is 23° and mean turning angle when the light is given from the left hand is 50°. All data from such animals were discarded.

e) Movements under a dark red light: Movements were observed under a 10 watt red light at a distance of 80 cm. and there were no fixed type of movements but straight and curved movements occurred. The typical circular movement was observed in only one case out of more than ten animals. The amplitude of the wavy movements increased in the dark, and the searching movement in the air occurred frequently when the head was held higher in the air, even one-third of the total body length being lifted. Searching movements in the horizontal plane also appeared more frequently. One example of these movements is shown in Fig. 1.

f) Thigmotaxis of the animal was examined under the dark red light, by using some glass rods as a contact object but it was proved that there is no thigmotaxis in the land planarians, as far as the lateral surface of body is concerned.

g) According to Cole (1907) the geotaxis of *Bipalium kewense* is so significant that by lifting very slightly the plane where the animal is creeping, it could be turned easily in any direction. In my experiment, however, the animal does not show such significant geotaxis.

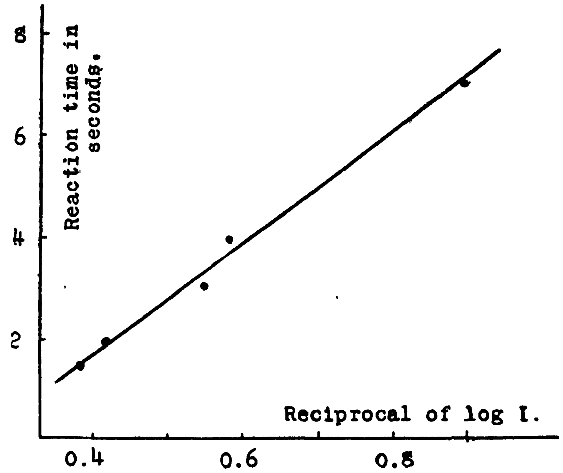


Fig. 2.

Relation between the reaction time and the reciprocal of the logarithm of the intensity. Each point represents the mean value of five animals; three readings for each animal for every intensity; room temperature 16°C.

4. REACTIONS TO SINGLE LIGHT SOURCE

a) Horizontal light beam

The animal reacts negatively even to the light of a one meter candle. The reaction time was measured in several intensities of illumination. There is a linear relationship between the reaction time and the reciprocal of the logarithm of the light intensity as shown in figure 2. This proves the fact that the photochemical effect (E) to produce the reaction in the animal is proportional to the product of the reaction time (t) and the logarithm of the intensity of the illumination (I), that is, $E=k. t. \log I$, where k is a constant, as studied by Hecht (1921). However, an attempt was made to analyse the effect of light into wave lengths and the amount of energy but conclusive results were not obtained, owing to the difficulties of fine determinations of the reaction time.

Generally, when the illumination is strong the reaction is clear and rapid, when the angle between the direction of the incident light beam and the direction of the animal is smaller, trial movements are correspondingly less frequent (Fig. 3). When that angle is maximum (180°) the animal is faced in the direction of the light beam, it often turns the head to and fro for several times, as shown in figure 3, c. In the case when the animal is placed perpendicular to the incident light beam and the shade of body is greatest, the largest wavy movement is seen, as shown in figure 3, d. With progression of forward movement, the amplitude of the wavy movement is gradually decreased and finally comes to the same state as in the case when it is put in a position parallel to the light beam, facing or away from the light (Fig. 3, a, b and c). There are no searching movements in the air when the light is sufficiently strong. When the animal has completely reacted to the light, the amplitude of the wavy movement is smaller according to the strength of the light. This is probably due to the fact that the sensory organ plays its function when it receives a definite amount of illumination.

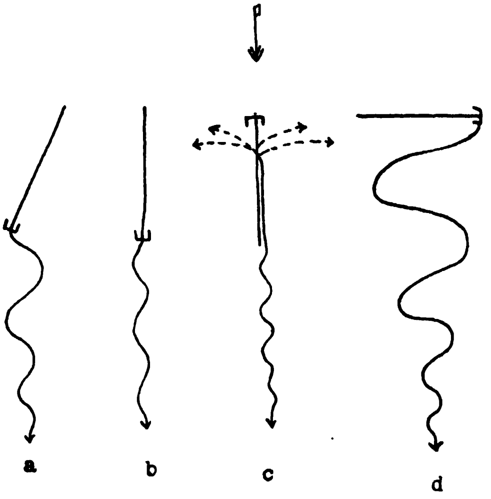


Fig. 3.

Diagram to show the reactions of land planarians in four different initial positions to one light beam. The direction of the light beam is shown by an arrow. The broken lines show searching movements. Further explanations in the text.

b) Reactions of animals to an inclined beam of light are essentially similar to those of the horizontal light but in the same intensity the amplitude of the wavy movements is smaller than in the latter case and the searching movements in the air are not to be seen even in a fairly feeble light.

5. REACTION TO TWO HORIZONTAL BEAMS OF LIGHT

a) The case of equal intensity of illumination

When an animal is placed in a field of two light beams of equal intensity, it reacts negatively phototactic, and gets away toward the bisector of the angle between the two light beams. The intensity of the illumination was 200 meter candles. The experiments were made with beams of light which intersect each other by angles of 60°, 90°, and 120° respectively. Results are given in the Table I. Each datum is the mean value, with its probable error of total trials with from seven to ten animals, each of which was used twice.

TABLE I

Angle between two light beams	Orientation angle, measured from one light beam
60°	30.0° ± 0.4°
90°	44.9° ± 0.6°
120°	59.5° ± 0.5°

Whether the animals were subjected to the two lignt beams simultaneously or the second beam was added after they had reacted to the first, the actual data of orientation angles were the same.

b) The case of different intensities of illumination

Light A was 200 meter candles and was kept constant. Light B was diminished into one-half or one-fourth of light A by increasing the distances from the animal, that is, 100 or 50 meter candles respectively. The angle between A and B was kept constantly at 90°. The experiment was worked out with seven specimens in each case. The data are given in Table 2. The data are the mean values of 14 experiments and their probable errors of mean, each specimen being used twice.

TABLE II

Intensity of light		Ratio of intensity of light, A/B	Orientation angle, measured from axis of B
A	B		
200 m.c.	200 m.c.	1	44.9° ± 0.6°
200 m.c.	200 m c.	1/2	52.7° ± 0.3°
200 m.c.	50 m.c.	1/4	58.1° ± 0.9°

Fluctuation of individual datum is fairly large.

The experiment of Cole (1907) indicates that *Bipalium kewense* showed a slightly larger number of turnings away from the stronger light when the animal was exposed to two different illuminations from opposite directions. That is, they have only a slight ability to discriminate between light intensities. But in this case the animal is very sensitive to the light intensity and numerical treatment is possible.

Northrop and Loeb (1923) proposed a formula in the study of the reaction of *Limulus* to two light beams,

$$\tan\alpha = I_1/I_2,$$

where α is the orientation angle of the animal when it is subjected to two illuminations I_1 and I_2 at right angles. The result of my experiments do not support this theory, and corresponds more adequately to the formula which has been given by Moore (1924) for the heliotropic reactions of *Cerianthus*. The formula is

$$k.\ \tan\alpha = \log(I_1/I_2),$$

where α is the orientation angle, I_1 and I_2 are intensities of illumination and k is constant. If this formula is right in our case, the values of k, calculated by inserting our observed data, must be fairly constant and it proved that values of k were 2.2 and 2.5 in this case.

The values of the "head angle" (H) of Crozier's formula (1927),

$$\tan\frac{H}{2} = \frac{I_1 - I_2\tan\theta}{I_1\tan\theta - I_2}.$$

where θ is an angle of orientation, were calculated and they were 132.3° and 133.3°. From these data it may be said that this formula is converted to the formula of Moore, in this case, as shown by Crozier.

Thus it is concluded that the tangent of the orientation angle of the animal, when exposed to the illuminations intersecting at a right angle, is proportional to the logarithm of the ratio of the intensities of the illuminations.

6. NOTE ON THE SIGNIFICANCE OF THE EYE SPOTS

Cole (1907) studied phototaxis and the function of the eye spots of *Bipalium kewense*, and considered that an individual eye spot is too small to form an image or even to detect the direction of light, but as a whole system they can react to light from all directions. I took this

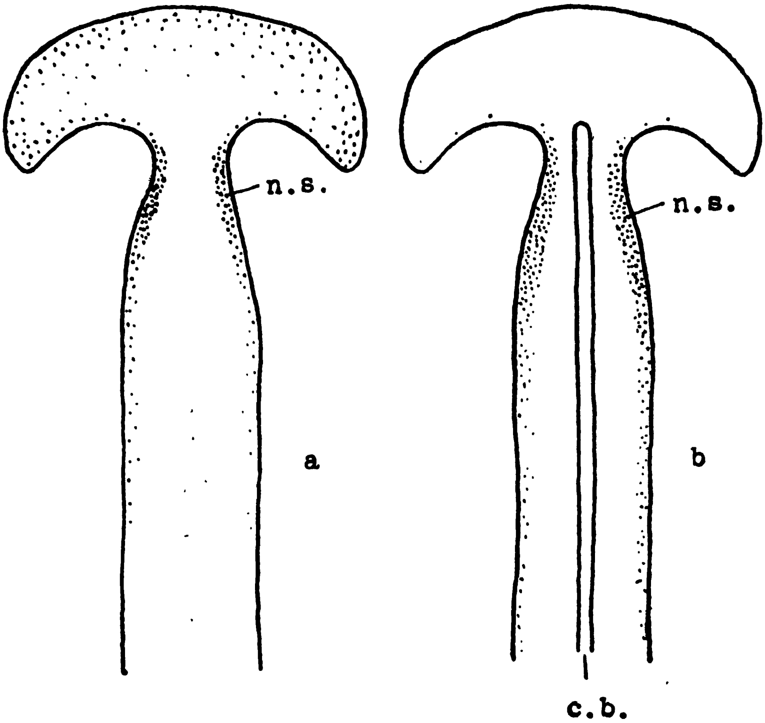


Fig. 4.

Diagrams showing the distribution of the eye spots in *Bipalium sp.*. Dorsal view (a) and ventral view (b) of about one-third of the anterior part of the body. A small dot shows an individual eye spot; n. s., the so-called neck spots; c. b.: a creeping ciliary band.

problem, therefore, to ascertain more about the eye spots and their correlation with the phototaxis of *Bipalium sp.*, which has many eye spots on definite portions of the body wall.

Concerning the distribution of the eye spots, v. GRAFF summarized the results in BRONN's "Tier-Reiches". In *Bipalium sp.*, the eye spots are assembled on the dorsal side of the head portion and the side wall of the neck and the succeeding anterior part of the body. The distribution of the eye spots is as shown in the Fig. 4, a and b. They are distributed most densely at the neck from the dorsal portion at the base of the head to its ventro-posterior part on each side of the body surface. Along the margin of the dorsal side of the head there are fairly numerous eye spots, especially on both lateral margins. Behind the neck spots there are only a few on the dorsal side, as shown in Fig. 4, a, while on the ventral side the eye spots are not found on the head, but a considerable number are on the neck portion farther back often extending two-thirds of the body length, although their numbers diminish gradually as they approach the caudal end. It is curious that the eye spots are distributed on the ventral parts of the side wall, where the light is less than on the dosal side.

In order to determine the function of the eye spots, we performed two sets of experiments, namely, the reactions of pieces of the body and the reactions of whole animal under the illumination which is given to several different parts of the body. When only the head is illuminated by a horizontal light beam it reacts very rapidly, which is probably due to the distribution of the eye spots and the modes of locomotion already described. When the neck portion is exposed to a horizontal light it reacts as rapidly as though the entire animal was exposed to the light. Illumination of the ventro-posterior part of neck has a slight effect on the animal, and illumination on any other part without eye spots shows no effect in the behaviour of the animal. An animal, when the right or the left projection of the head is cut off (Fig. 5, a or b), reacts normally to a horizontal light, but occasionally turns towards the intact projection, exposing the wounded surface to the light. When both projections are cut, the animal curves up the wounded surface and seems to react a little slower than is normal but after more than 15 minutes the animal can react almost normally. When the entire head is cut off (at c Fig. 5) it reacts a little more slowly than in the case of the head being intact, but no irregularity is found. In this case the rapidity of the reaction does not return for several minutes, as in the former case, and in such an animal without a head the speed of locomotion is very slow and the amplitude of the wavy movements diminishes extremely. A piece of the body which is decapitated and decaudated (at c and d of Fig. 5), reacts essentially simillar to the decapitated animal, but differs from the latter in its activity and in the stability of the pieces. According to the stability of the piece, such a piece creeps at first by holding up the cut surfaces and the side walls of the body but it frequently inclines to the right or left and consequently the side wall comes into contact with the creeping surface, and it often lies on that side. The other middle piece, cut from lines d and e of Fig. 5, and the caudal piece react no more to the light and this corresponds to the fact that eye spots are wanting in these regions.

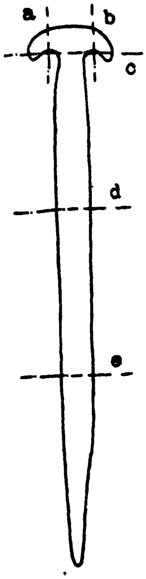


Fig. 5.
Diagram showing the position of cutting in the experiments.

From these results it is concluded that the number of the eye spots is an important factor, and the densest portion, as the neck region, is the most important portion in sensitivity in this animal. Both sides of the neck with eye spots are the main center of the photosensory system and the band of eye spots on the margin of the head, the hinder neck portion follows them in importance.

Now, it may be considered that the eye spots constitute a system of photosensation in *Bipalium sp.* and it consists of three districts, one on the dorsal side of the head and the other two on both sides of the body, centering on the neck portions. Thus we shall understand the phenomena more clearly.

7. UNSTABLE POSITIVE PHOTOTAXIS

In studying the reaction of the animal to horizontal light beams from two different sources we encountered a curious phenomenon in which the animal reacts positively to the light. When the animal is placed nearly on the bisector of the angle of the axes of two beams of light, facing their sources, it often proceeds forward with a large, wavy motion and several searching movements in a plane. Such reactions will occur frequently when the animal is starved or fatigued.

The phenomenon may be explained as follows; if an animal is placed in a certain place where the intensity of the illumination is stronger on the right hand than on the other, then it may turn to the left according to the theory of tropism. But if the illumination on the left side becomes stronger than on the right when it turned to the left, it must be driven to the right again by the photosensitive effect of the left side, thus the animal is forced to move on toward the lights, positively phototactic on the bisector and this is an unstable equilibrium of phototaxis. These explanations are supported by two facts; primarily, the percentage of occurance of this phenomenon increases with an increase of the angle between the axes of the two light beams, for instance, the percentages of occurrence are 0%, 5%, and 48% in the cases of angles of 60°, 90°, and 120° respectively; secondarily, it is acertained that the head angle of CROZIER's formula was about 130° in *Bipalium* and this is the limit of the angle in which the animal can orient itself freely to the light, therefore if the angle between the axes of two light beams is larger than this angle the animal cannot definitely orient itself.

8. SUMMARY

1. Modes of reaction of land planarians to several circumstances of illumination are described.

2. Some attempts have been made to analyse the nature of the negative phototaxis.

3. *Bipalium sp.* is very sensitive to the light and follows the law which has been deduced from other photosensitive animals.

4. Distribution of the eye spots in *Bipalium sp.* is described.

5. Some attempts have been made to analyse the meaning of this distribution and it was seen that the neck portion is the most sensitive and the main center of phototaxis.

6. A curious phenomenon of positive phototaxis is explained.

9. BIBLIOGRAPHY

COLE, J. L., An experimental study of the image-forming power of various types of eyes. Proc. of Amer. Acad. Arts. Science, 17, 335-417, (1907).

CROZIER, W. J., The orientation of animals by opposed beam of light. Journ. Gen. Physiol. 8, 671-684, (1927).

GRAFF, v. L., Bronn's Klassen und Ordnung des Tier-Reiches, IV. Vermes. p. 2917, (1917).

HECHT, S., Time and intensity in photosensory stimulation. Jour. Gen. Physiol. 3, 367-373. (1921)

MOORE, M. M., The relation of Cerianthus to two sources of light. Jour. Gen. Physiol. 4, 393-401, (1924).

NORTHROP, J. H. and LOEB, J., The photochemical basis of animal heliotropism. Jour. Gen. Physiol. 5, 581-595, (1923).

ROSE, M., La question des tropismes. 166-172. (1929).

TALJAFERRO, W. H., Reactions to light in Planaria maculata, with special reference to the function and structure of the eyes. Jour. Exp. Zool. 31, 59-116, (1920).

ON THE PHYSIOLOGY OF LAND PLANARIANS

II. Galvanotaxis

(With 4 Text-Figures)

Siro KAWAGUTI

(Accepted for publication, September 8, 1932)

CONTENTS

1. Introduction 29
2. Material and method 30
3. Experiments
   A. Reactions of the intact animals 31
   B. Reactions of mutilated animals 33
4. General remarks 35
5. Summary 36
6. Bibliography 37

INTRODUCTION

After the study of the galvanotaxis of *Polycelis nigra*, ROBERTSON (1927) reached the conclusion that the theory of galvanotaxis according to its inherent electrical current is applicable, even though it is too small to explain completely his theory.

In the study of land planarians, the writer found that they react somewhat differently from *Polycelis* to an electrical current. Besides the materials are sufficiently large, they are terrestrial in habit, and are

---

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Uuiv., Formosa, Japan, Vol. VII., No. 1, October, 1932.]

animals in which the surface of contact is limited to a creeping surface, one narrow median ventral ciliary band. It is very interesting to compare the results with aquatic froms in which currents flow through almost all the body surface and probably a few at the contact surface, where the ciliary motion is most active.

MATERIAL AND METHOD

The material used was *Bipalium sp.*, which was collected in the vicinity of the University, and was used for experiments within two days after collection.

The experiments were carried on with the apparatus shown in Fig. 1. A is a creeping surface on a wooden table 17 cm. in height. It is a filter paper, 30 cm. long and 20 cm. wide, moistened with $\frac{1}{4}$ artificial sea water,(1) and spread on a glass plate. B and B′ are glass vessels of adequate size, each containing $\frac{1}{4}$ artificial sea water and connected with A by a bridge of filter paper of definite breadth. D and D′ are glass vessels containing about 5 percent $CuSO_4$ and the electrodes are immersed within. D or D′ is connected to B

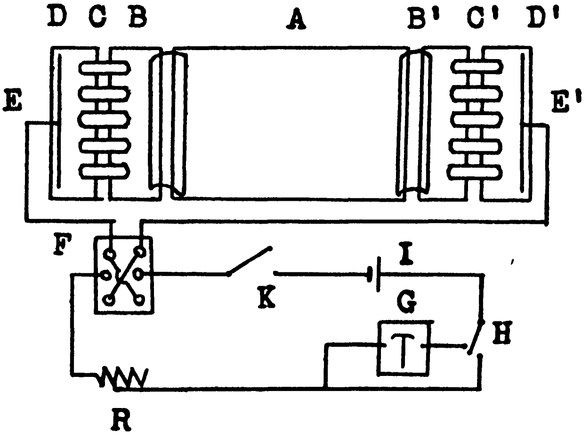


Fig. 1.

Diagram of the apparatus. A, Experimental table. B, B′, Glass vessels. C, C′, Bridges. D, D′, Glass vessels containing $CuSO_4$. E, E′, Electrodes. F, Commutator. G, Milliammeter. H, Key to milliammeter. I, 60 volts dry cell. K, Key for the current. R, Rheostat.

---

(1) Components of the 1/4 artificial sea water are as follows;

$NaCl$	............80.4×1/10 gm. in 1 liter,
KCl	.... 4.6×1/10 gm. in 1 liter,
$CaCl_2$	.... 5.6×1/10 gm. in 1 liter,
$NaHCO_3$	.... 2.1×2/10 gm. in 1 liter.

It has been pointed out by several authors that the direction of galvanotropic orientation might be changed by different chemicals. (ROSE, 1929) or B′ by five U-tubes (C or C′) which were filled with cotton. Both electrodes E and E′ are connected to a dry cell of 60 volts (I), through a commutator F), resistance (R) are a milliammeter (G); K is a key which makes the current, H is a key of the current through the ammeter.

Although ROBERTSON used an intermittent current and a constant current in his study of galvanotropism of *Polycelis*, in my experiments a constant current only used, as the intermittent current produces the effect of a back current, which appear when the circuit is off and the effect becomes greater when the frequency of intermittence is increased. It is difficult to clearly define the direction of an effective current in such a case, even though the intermittent current is more effective than the constant current, as he says.

As these animals react very sensitively to light, the experiments were done under a dark red light which can be considered as a diffused light in a dark room. Experiments were done during March and April of 1931 and during that period the room temperature was 18°–20°C.

EXPERIMENTS

A. Reactions of the intact animals.

1) Reaction to a weak current (0.3–0.5 milliampers)

When the animal is subjected to the current on the line of the current with its longitudinal axis and facing the cathode, it contracts the body by drawing the tail and loops to the cathode, in this case the margin of the head projection flatly contacts the creeping surface; if the current is reversed it elongates and crawls forward with a ciliary movement, holding the head as normal, a little above the creeping surface, but the direction of the head is not definite; in a few cases it is exactly toward the anode. When the animal is placed perpendicular or oblique to the current it reacts normally with ciliary gliding, as if there were no current, but it proceeds rather to the anodal side than to the cathodal.

2. Reactions to a current of medium intensity, (1 m.a.–3m.a.)

The essential features are similar to those of low intensity, but the contraction is stronger and ciliary gliding only appears in a very few cases. When the animal is exposed for a sufficiently long period to a current of 3 milliamperes in a position perpendicular or oblique to the direction of the current, the normal ciliary creeping occurs, especially to the cathodal side and rarely it contracts the body in the form of a C-shape, bending the head and tail to the cathode while the ventral side faces the anode or, less frequently, the cathode. If the animal is placed by bending the body in a position so that the anterior half is facing the anode and the posterior half the cathode as shown in Fig. 2, the anterior part elongates toward the anode and the posterior half contracts by drawing up the end.

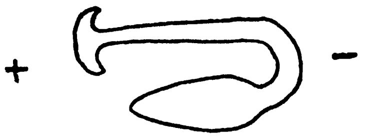


Fig. 2.
Diagram showing the reaction to a weak current, the anterior elongated half, facing the anode, and the posterior contracted half, facing the cathode.

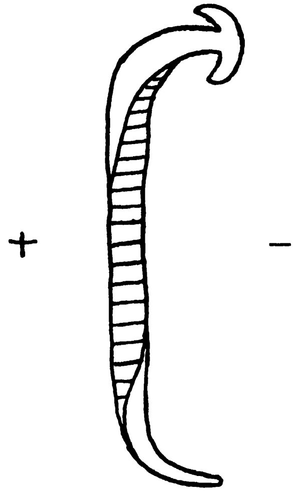


Fig. 3.
Diagram showing reaction to a strong current when the longitudinal axis is perpendicular to the direction of the current. Dorsal side is shaded.

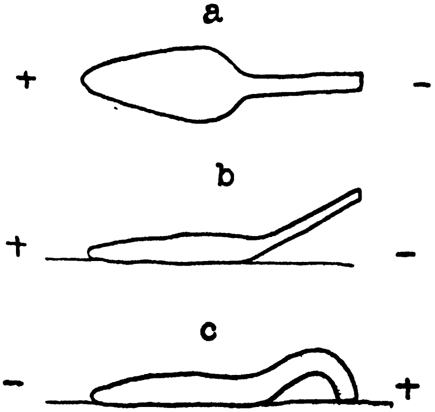


Fig. 4.
Diagrams showing the reactions of the caudal piece just after cutting, when subjected to the current as indicated in each case; a, dorsal view, b and c, side views.

When the animal is placed on the dorsal side on the creeping surface and the current is made in the direction from the head to the tail, it elongates and immediately a righting reaction follows; by the change of the direction of the current it contracts, as in the normal case, by putting the head on the creeping surface and it remains in that position without trying to right itself or to loop forward.

3. Reactions to a strong current (6-7milliamperes)

Such a current seems to be very strong for this animal and it is difficult to recognise smooth ciliary gliding. In a few cases, it loops vigorously to the cathode. The animal shows a painful convulsion and protrudes the pharynx. If the direction of the current is through the head to the tail, it contracts vigorously, elongating the tail portion towards the cathode, and frequently the head is bent upward until it falls on the side of the body and faces the cathode. When the current is made through the tail to the head, the reaction is essentially similar to the case with a current of medium strength, but it contracts more vigorously and loops less frequently. When the animal is in a position perpendicular to the current, it bends the head to the cathode by twisting the anterior part of the body, contacting with the dorsal side of the head the creeping surface, while the ventral surface is exposed upright; the tail portion also turns to the cathode but the ventral surface faces the cathode, as shown in Fig. 3. When the direction of the current is turned, the animal restores its original position and then reacts in the same manner.

B. Reactions of mutilated animals

When the animal was cut into three pieces and kept for one hour before the experiment, there is no effect from the cutting at the time, as far as the demarcation current is concerned. If the middle or tail piece is exposed to the current just after the cutting it reacts somewhat differently. When that part is faced toward the cathode, it holds up the anterior part with the cut surface by elongating into a slender form, and contracts the other part of the piece, as shown in a, b in Fig. 4, and if the current is reversed the cut surface is firmly pressed to the creeping surface. These reactions are reversed after a sufficient time. This is the interpretation of the presence of the demarcation current at the cut surface, from which current it is free after an hour.

1. Reactions to a medium current

The velocity of locomotion is very slight in the middle and tail pieces. All three pieces, when their anterior ends are faced to the cathode, contract and loop to the cathode; when the current is reversed they elongate the body and proceed to the anode by a ciliary gliding movement. In these cases they move obliquely to the electrodes or a wandering course is often traced, but on the whole the reactions were well-marked and are essentially similar to those of an intact animal. Backward ciliary movements and looping, as seen so often by ROBERTSON in *Polycelis*, were not observed.

When these pieces are placed on their dorsal sides their reactions to the current are similar to those of entire animals, when their anterior ends are faced to the cathode they contract and remain in that position but facing the anode they elongate and righting reactions occur.

2. Reactions to a strong current (6-7 milliamperes)

The head piece reacts very differently than in the other cases, the reversed reactions occur, as it elongates when it is faced to the cathode, without looping or ciliary movement, and contracts when facing the anode. When it is placed upside down it elongates in both cases whether facing the cathode or the anode, but in the latter case there occurs the righting reaction. The middle piece reacts the same as with the medium current, but when the anterior part faces the cathode it sometimes turns up until the whole piece is turned over to the reversed direction, consequently, the anterior part faces the anode, which is anodal galvanotaxis. In the caudal piece such reaction occurs more frequently. Other reactions are almost similar to those with a medium current.

GENERAL REMARKS

ROBERTSON (1927) considered that the bio-electric current is correlated with the metabolic gradient or the susceptibility gradient for plasmolytic substances, as actually proved by HYMAN and BELLAMY (1922) in *Planaria*. He explained galvanotaxis with these bio-electric currents, as was considered by HYMAN and BELLAMY, and confirmed his idea by reactions as follows: *Polycelis* proceeds to the cathode when exposed to the current, and when the tail of the decapitated animal is faced to the cathode, it loops to the cathode by backward movements. In a strong current the animal bends the head and the tail to the cathode and the ventral surface faces the cathode.

Recently HYMAN (1932) published her further confirmation that galvanotaxis of planarians might be correlated with the electrical potential gradient. It was shown that the fissioning planarians, having a secondary positive charge at the fission plane, assumed a U- or W-shaped orientation in the current, and that the non-fissioning species, in which the potential gradient is single, oriented parallel to the current.

ROBERTSON did not consider the fact that the most active ciliary movement is on the ventral side, where, according to the theory of metabolic gradient, there might be a positive electrical charge, and that looping is an abnormal movement, as the looping to the cathode might occur even when the ciliary beats were forced to stop.

In the case of *Bipalium*, it differs greatly from *Policelis* and *Planaria*, as to its morphological structure and its physiological conditions. It is slender in form and its creeping surface is limited in a narrow band on the median line of the ventral side. The susceptibility experiment on *Bipalium* shows the existence of double metabolic axial gradients, as the head is higher than the tail and the middle is the lowest. It is difficult to apply ROBERTSON's hypothesis of electric current in *Policelis*, as it creeps to the anode with a smooth, normal ciliary movement, (even if it loops to the cathode when the anterior end is pointed to the cathode) and in a strong current it shows the C-shaped reaction, turning over its ventral surface to the outside.

Thus it is supposed that the electrical potential in the ventral ciliary band is lowest at the anterior portion and increases toward the posterior end, while the potential in the interior of the body is highest at the head and decreases toward the posterior. The experiments with intact animals and cut pieces in normal inversed positions agree with this conception. These double electrical polarities in *Bipalium* cause diphasic galvanotropism, that is, the animal creeps to the anode with a ciliary motion and if it faced to the cathode it loops to the cathode. This same point I can also explain by the change in electrotonus as did several authors (ROSE, 1929). The animal facing the anode with the head suffers catho-electrotonus (increase excitability) at the tail but not at the head, therefore it runs away from the injury and proceeds to the anode with normal ciliary glidings; on the contrary if the current is reversed it suffers from catho-electrotonus at the head and contracts the body. According to its nature of crawling forward by ciliary motion and the internal electrical potential differences which cause the tendency to run to the cathode, it is forced to loop to the cathode. Among the reactions to a strong current, the most interesting case is that when the animal is placed perpendicular to the current, it turns its head and its tail to the cathode with the head portion turned over on its back, the tail portion points to the cathode by the bending the body, the ventral surface faces the cathode (Fig. 3). These reactions suggest that in the head portion there is high electrical potential, especially on the dorsal side, and in the caudal portion there is a similar high electrical potential on the ventral side.

But, this being mere assumption, further explanations must be given after the measurement of real potential differences. As the reactions are often irregular, and differences in the muscular and the nervous systems may effect greatly the reactions, the exact determinations cannot be obtained by this method of galvanotropism; moreover it is difficult to acertain the current spread in these cases.

SUMMARY

1. Reactions of land planarians to the electrical current are described.

2. Land planarians react differently from aquatic planarians.

3. Two electrical potential gradients are supposed to explain certain reactions, the one existing at the ventral ciliary band, lowest at the anterior and gradually increasing toward the posterior end, and the other in the interior of the body, having reversed potentials.

BIBLIOGRAPHY

HYMAN, L. H., Studies on the correlation between metabolic gradients, electrical gradients, and galvanotaxis. II. Physiol. Zool. 5, 185-190. (1932)

HYMAN, L. H. and BELLAMY, A. W., Studies on the correlation between metabolic gradients, electrical gradients, and galvanotaxis. Biol. Bull. 43, 313-47. (1922)

ROBERTSON, J. A., Galvanotropic reactions of *Polycelis nigra* in relation to inherent electrical polarity. Brit. Jour. Exp. Biol. 5. 66-88. (1927)

ROSE, M., La question des tropism. 246-296. (1929)

ON THE PHYSIOLOGY OF LAND PLANARIANS

III. The Problems of Desiccation

(With 9 Text-Figures)

Siro KAWAGUTI

(Accepted for publication, September 8, 1932)

CONTENTS

1. Introduction. 39
2. Material and methods. 40
3. Results. 41
    - a. Rate of evaporation, in relation to the size of the animal. 41
    - b. Relations between the body weight and the length or breadth of the body in the active state, and between the body weight and the evaporating surface area in the resting state. 43
    - c. Amount of residue after desiccation. 45
    - d. Effect of relative humidity on the rate of evaporation.... 47
    - e. Effect of temperature on the rate of evaporation. 48
    - f. Recovery from desiccation. 50
    - g. Limit of desiccation without killing. 51
4. General remarks. 53
5. Summary. 54
6. Bibliography. 55

INTRODUCTION

Physiologists were attracted to the problem of desiccation already in earlier days and follow its process in recent years. HALL (1929) studied

---

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VII., No. 1, October, 1932.]

the problem in salamander, snake, *Peromyscus*, turtle and house mouse. GRAY (1928) followed the desiccation of newt and lizard in the intact and the skinned animal. BUXTON (1930) studied evaporation in the meal-worm under different relative humidities. SMITH and JACKSON (1931) measured the change of weight in several organs of the frog in desiccation, and their recovery when immersed in water. ADOLPH (1932) studied desiccation and recovery in the intact, pithed, and skinned frogs under several relative humidities, and showed that the rate of evaporation was almost inversely proportional to the relative humidities of the atmosphere.

Among the conditions which suffice for the maintenance of terrestrial life in the land planarians, the mode of resistance to desiccation is one of the most important. When they were kept in dry air, their body weight decreases rapidly and consequently they are killed in time, as frequently can be seen on a concrete wall on bright mornings. Such a dried carcass weighs only one-fifth of the initial body weight.

Although land planarians present favorable material for studying the problem of evaporation because of the simplicity of their organization, there is no paper on the problem.

MATERIAL AND METHODS

The *Bipalium sp.* used was collected on the University grounds and was kept in an earthern flower-pot for about one day before the experiment, with wet soil and grasses as humidity regulators.

The experiments were made with materials which had been kept in a definite condition or in a state of saturation with water. They were weighed on an analytical balance at the beginning and at frequent intervals during the desiccation and the recovery from it. The material was kept during the experiment in a shallow glass dish with a cloth cover held on with a rubber band. It was weighed by being taken out of the dish and transferred to a definite glass vessel, a beaker of 50 cc. capacity. Strictly speaking, the loss in body weight, measured in such a way, is not equivalent to the loss of water or the amount of evaporation and includes the loss of weight caused by excretions, respiration, etc. but ordinarily it is considered as approximately the amount of evaporation as these factors are insignificant and negligible.

The specimens controlled under the conditions mentioned above produce no faeces. Occasionally the animal produce faece-like substances, probably substances from auto-disintegration. During the course of desiccation the disintegration often begins from the head and less frequently from the tail, especially at higher temperatures. Notes from such materials were discarded.

The experiments were done at room humidity and room temperature, excepting that on the effects of temperature and relative humidity in which the experiments were done in a chamber of constant relative humidity, over a definite concentrated solution of sulfuric acid. Their concentrations were computated from the specific gravities. The vapour tensious of the solutions were obtained according to SHELFORD, 1928, p. 252.

The experiments were partly carried out in March, 1931 and partly in June, 1932. During both seasons the weather was rainy and the relative humidities were 75-82%, while the temperature was 20-23°C in the former season and 25-30°C in the latter.

RESULTS

a. Rate of evaporation in relation to the size of the animal

In order to determine the effect of the size of the body on the rate of evaporation, several animals of different sizes were kept in a relative humidity of 80-82% at a room temperature of 20° ± 1°C and weighed every two or three hours for about one day.

The results are given in Fig. 1. From these data the loss of body weight in each animal shows a linear relationship to the time of desiccation. Therefore, there is no mechanism resisting desiccation until the lost reaches 60 per cent of the total body weight. The relation seems to be different when desiccation exceeds 60 per cent, as shown in a later part.

The linear function may be expressed as follows:

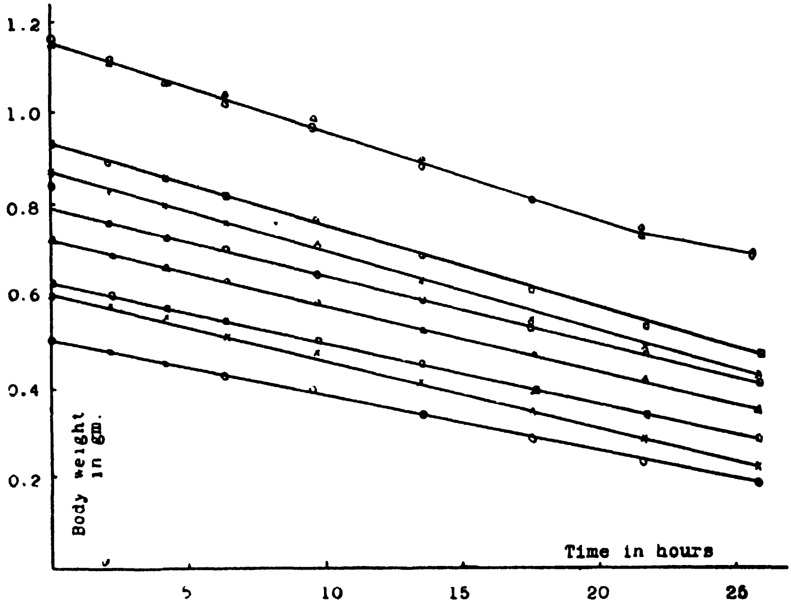


Fig. 1.

Showing the change of body weight during desiccation, in a relative humidity of 80%, at 20° C.

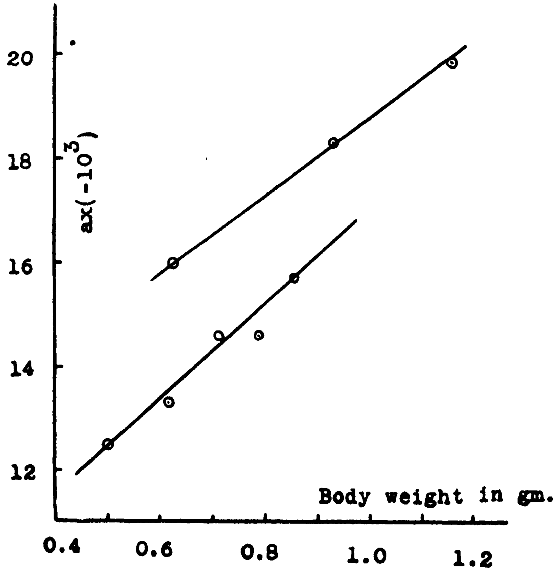


Fig. 2.

Showing the relation between body weight and evaporation coefficient (a).

$$W = aT + b$$

where W is the body weight, T is the time of desiccation, a is a constant, and b is a constant corresponding to the initial body weight. The values of a and b are calculated in each case, and plotted in Fig. 2 in which the value of the evaporation coefficient (a) increases with the increase of the body weight (b) and such relations between them are expressed by two straight lines. The upper line is considered to be the relation in the animal in the active state when it loses its body weight more rapidly than in the resting state. The lower line shows the relation of animals in the resting state and the notes show actually the active or resting states corresponding to the results. Thus, in both cases, the resting and the active state, evaporation seems to be controlled by the linear function of body weight. From these findings it is desirable to use material of approximately equal size for the comparision of the rate of desiccation. Material ranging from 1.0 gm. to 1.5 gm. were used and the percentage loss of the body weight to the initial body weight was used for the comparision instead of the absolute value of the loss by weight.

Such linear relations between the time of desiccation and the amount of evaporation have been reported by several authors for *Salamander*, turtle, snake, meal-worm, and frog.

b. Relations between the body weight and the length or breadth of the body in the active state, and between the body weight and the evaporating surface area in the resting state

Already it has been shown that the rate of loss in the body weight retains a linear relationship with the body weight as a whole and it is also well known that the rate of evaporation is proportional to the surface area. Then in this case simple relations may be supposed between body weight and body surface area, either in the active or the resting state. Calibration of the surface area of body in the active state is a most difficult matter, as it is in a wavy position and the whole surface contacts the air, excepting the crawling ribbon at the ventral median line. The shape of the cross-section differs according to the position of the body. Moreover, the air coming into contact with the body surface increases with locomotion and effects greatly the amount of evaporation. In the resting state the calibration of the surface area is simple, as the body is flattened and the boundaries fixed but even then there often exists some folds. The figure of an animal in the resting state on a glass plate was drawn from the under surface on a tracing paper and measured with a planimeter. Such an area is considered to be an evapo-

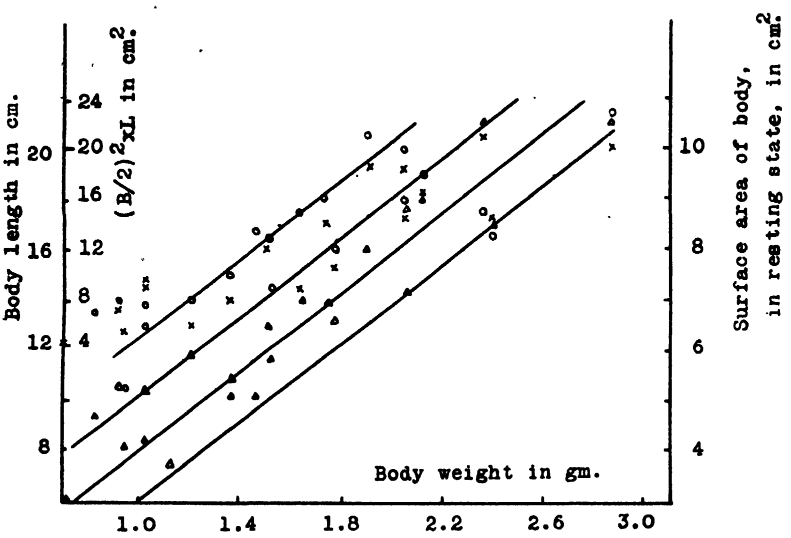


Fig. 3.

Showing the body length in the active state (expressed by the circle), product of body length and square of a half breadth in the active state, (expressed by x), and free surface area in the resting state (expressed by the triangle) of different body weights.

rating area, as in the resting state only the dorsal surface is in contact with the air.

The length and breadth of the body in the active state were measured in sevejal cases; as in the case of the surface area, the figure was dawn from the oposite side of the glass plate where it was crawling, and was measured by a curvometer. These data are given in figure 3.

From these figures it is understand that a linear relationship between the body weight and the evaporating surface area exists in the resting state, in accordance with the results of the previous section. Thus it can be said that the rate of evaporation may be proportional to the surface area within the range of these materials. The equation seems to be expressed by

$$S = C.W,$$

where S is the body surface area in terms of cm^2., and W is the body weight expressed in gm., and C is a constant, 3.96. But in the case of smaller animals the relations seems to be different, as the surface is larger than that calculated from this formula. Therefore in smaller animals, the rate of evaporation is much larger than in the large ones. This also is probable from the fact that the evaporation is more efficient at the boundaries than in the middle portion and the ratio of the surface area to the length of the boundary is markedly decreased when the body weight is less than 1 gm.

The relations between the weight and the length of the body in the active state may also be expressed by a similar straight line with this range of materials, but it is not so distinct. Then the products of the length and the square of half the breadth were calculated and plotted in the figure. Relations between body weight and these data are very significant, as might be expected.

c. Amount of residue after desiccation

The residues after desiccation have been measured in eleven cases, each with a different initial weight. The material was kept in a desiccation chamber over "Adsole" about for three days until further decrease of weight became difficult to observe. The results are given in Table 1.

The amount of residue in the percentage of the initial body weight seems to have approximately constant values. Therefore, animals contain water in an equal rate. The mean percentage content of water was 82.2±0.27 per cent of the initial body weight. These data of the water content are slightly larger than the data of BUCHANAN (1930) in planarians in which the mean value of the water content was 79 per cent.

In order to determine whether the contents of the dry substance shows an axial gradient, as shown by HATAI (1924) in earthworms, but which failed in planarians as done by BUCHANAN (1930), the following experiments were done. The material was cut into three pieces of approximately equal size; these were kept separately in an experimental dish for weighing several times until desiccation was finished. The value of each desiccated residue in per cent of the initial weight is given in Table 2. The reason why the initial weight of a cut piece is taken instead of the whole animal is because the sum of the weight of the three pieces is smaller than the weight of the whole intact animal

TABLE 1.

Amounts of residue after desiccation and percentage of water contents of land planarians.

Initial body weight in gm.	Residue in gm.	Residue in per cent of initial weight	Total water content in per cent of initial weight.
2.048	0.367	17.9	82.1
1.835	0.330	18.0	82.0
1.464	0.244	16.7	83.3
1.374	0.286	20.8	79.2
1.208	0.215	17.8	82.2
1.114	0.195	17.5	82.5
1.020	0.182	17.9	82.1
1.018	0.163	16.0	84.0
0.945	0.170	18.0	82.0
0.889	0.147	16.5	83.5
0.621	0.116	18.7	81.3
	Mean values	17.8	82.2±0.27

measured just before cutting, probably due to the loss of body fluid. The amount of loss of the body weight by cutting reached in some cases 5 per cent of the whole initial body weight.

TABLE 2.

Desiccated residue of cut pieces, in percentage of initial weight.

No. of Specimen.	Head.	Middle.	Caudal.
c 21	19.9%	18.4%	19.0%
c 22	16.3	17.2	16.7
c 23	18.1	19.4	14.6
c 24	19.5	18.5	16.9
c 25	22.7	21.6	18.5
Mean	19.3%	19.1%	17.1%

From these figures it may be said that the caudal portion contains more water than other portions. Notwithstanding that BUCHANAN reported differences in the rate of desiccation in the head and caudal pieces, no such differences were observed in this case.

d. Effect of relative humidity on the rate of evaporation

Fig. 4 shows the results of the loss percentage of body weight in several constant relative humidities, each point representing the mean value of from three to five experiments. In these figures, the percentage loss of body weight increases with the decrease of relative humidity and there is a regular loss of water even in air of saturated humidity, as has been reported in the frog by ADOLPH (1932). The amount of loss is estimated as 1.1 per cent per hour. ADOLPH's theory on the mechanism which causes such evaporation may be applicable also in my case.

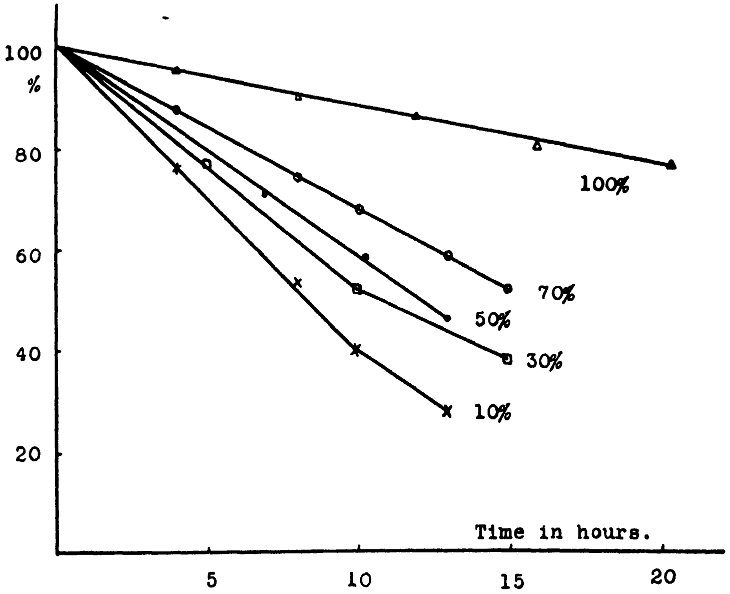


Fig. 4.

Showing the relations between the percentage body weight and exposure time in 100%, 70%, 50%, 30% and 10% relative humidity at 28-29°C. Each line shows the mean value of from two to five specimens.

At 70 per cent relative humidity the loss of water increases greatly and it is 3.2 per cent per hour. The percentage loss of body weight per hour is 4.1, 4.8, and 6.0 at 50%, 30%, and 10% relative humidities respectively, as presented in Fig. 5.

The lower two lines in Fig. 4 show the decrease of the rate of loss of body weight in the later course of the experiment. The cause of this decrease may exist in a modification of the evaporating mechanism, or more exactly, the state of evaporating water during the earlier course, from 0 per cent to 50 per cent of the body weight, differs from that of the later course, from 50 per cent to 82 per cent. That is, the water remaining after the evaporation of 50 per cent of the body weight may play a different role from that already evaporated, the latter being most important to the maintenance of life, as shown later in the recovery experiment.

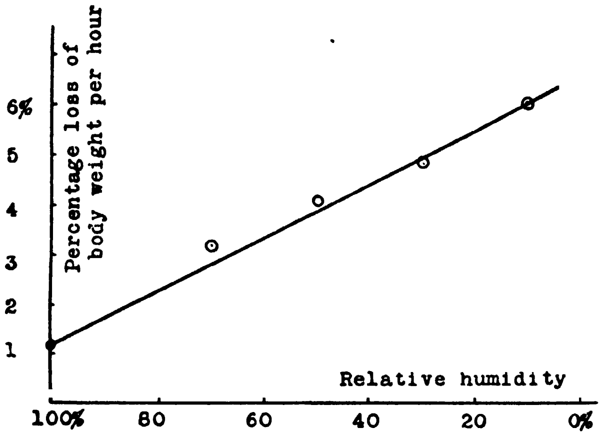


Fig. 5.

Showing the percentage loss of body weight every hour in several relative humidities, at 28–29° C.

Although in 70 and 50% relative humidities the relative rate of evaporation is a little higher, the relations between the percentage loss per hour in relation to the relative humidities can be expressed by a straight line.

When the vapour pressure of saturation deficient at that temperature was given in place of the relative humidity, the relation seems to be similar.

e. The effect of temperature on the rate of evaporation

The effect of temperature on the rate of evaporation was examined at different degrees. The changes of body weight can be expressed by the straight line in each case, as in other cases. Then the comparision of the rate of loss of body weight per hour is sufficient to discuss the results. They are given in Fig. 6, which shows that temperature acts very effectively at higher temperatures, particularly at higher than 30°C.

At 35°C and 70% relative humidity land planarians lose their body weight about 7% in every hour, then the loss of weight may reach 60 per cent within 9 hours and further desiccation kills the animal, partly or totally according to the limit of desiccation, when the animal regains the water.

If the vapour pressure of the saturation deficient at each temperature is taken in place of the temperature, the relation seems to be different, as shown in Fig. 6. (The pressures were calculated from the table of Landolt's "Tabellen".) The rate of evaporation at a definite relative humidity and at several temperatures can be expressed by a linear function of the saturation deficient. From this fact we can say that the effect of high temperature is not physico-chemical or physiological, but a simple physical one.

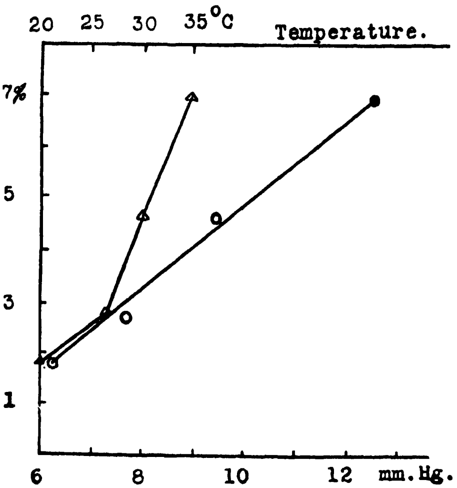


Fig. 6.

Percentage loss of body weight at several temperatures with a relative humidity of 70%. Ordinate shows the loss of body weight per hour in per cent of the initial body weight. Abscissa shows the temperature (represented by triangles), and the vapour pressure of saturation deficient at each temperature in mm. of Hg. (represented by circles).

Then, the rate of evaporation (E) may be expressed by the following equation,

$$E=a(F-f)+b,$$

where a is a coefficient of evaporation, F is the saturation tension of vapour at that temperature, f is the vapor pressure, b is a constant which correspond to the rate of evaporation in saturated air.

f. Recovery from desiccation

When the desiccated land planarians are placed on a wet filter paper or on absorbent cotton, they remain at rest and regain their body weight by absorbing water. This water seems to be regained through the skin which contacts the wet substances. As the experiments on the head or the caudal piece without the mouth portion show similar results, the water swallowed through the mouth may be neglected. The regain of body weight was followed until the weight reached constant.

In the beginning, the forms of recovery of the different body weights were studied. The animals were desiccated as in the desiccation experiment, at room temperature (29–30°C), and at the relative humidity of the room (about 75–80%), until the body weights reached about 60 per cent of their initial weights. Then they were placed on an absorbent cotton, wet with tap water, and kept in a moistened chamber. The form of the swelling curve resembles the swelling curve of gelatin, as shown in Figs. 7 and 8. In each case, the rate of intake of water is

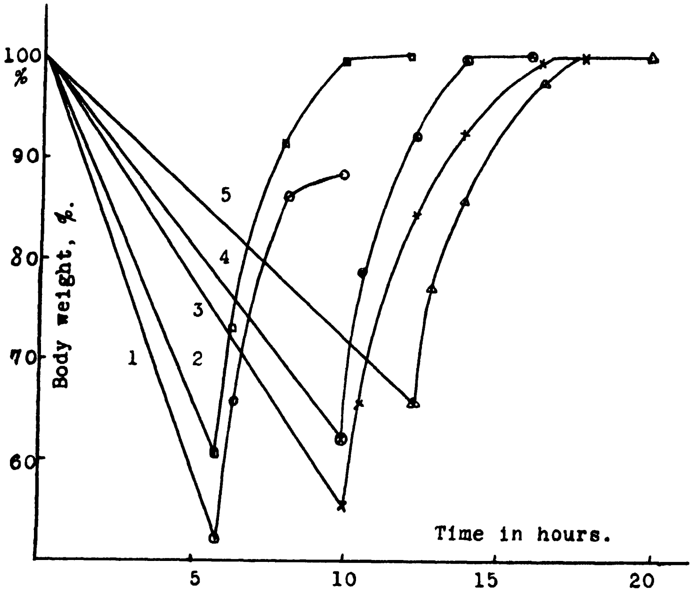


Fig. 7.

Showing the differences of processes of desiccation and recovery in differences of body weight. Each curve shows an individual experiment with material of 1 (0.57 gm.), 2 (0.78 gm.), 3 (1.27 gm.), 4 (1.37 gm.), and 5 (2.35 gm.). Each straight line shows the process of desiccation; at the extremity recovery set in.

largest at the beginning and gradually decreases as it approaches the original weight. SMITH and JACKSON (1931) obtained a rather linear relationship in the recovery phase of the desiccated frog, *Rana pipiens*, but ADOLPH (1932) presented a figure which resembles very closely my results with the same material.

The rate of swelling, also, seems to depend on the size of the material. The smaller animal swells more rapidly than the large one. The absolute amounts of gain of water were calculated in several typical examples, the average value was 0.102 gm. per hour for one animal, of which the average body weight was 1.27 gm. The surface area, where the regain of water may take place, can be computated from Fig. 3. Then, the gain of water per hour per cm^2. of body surface is 0.0204 gm. This is more rapid than the fastest evaporation.

g. Limit of desiccation without killing

Several animals were desiccated in the usual way, and were placed on wet absorbent cotton when they reached about 90%, 80%, 70%, 60%, 55%, 50%, and 40% of the initial weight. The processes of recovery were followed and the results were summarized in Fig. 8.

Almost all the specimens completely recovered their body weight, except the last two cases, 50% and 40%. In these cases at first the body weight increased but the disintegration of the head followed. When desiccation is not strong enough such disintegration occurs only at the head but if the desiccation is strong enough disintegration spreads to the whole body. For example, if the animal is desiccated until the body weight reaches 30 per cent of the initial weight, it disintegrates all over the body when it regains the water.

These phenomena are interpreted to mean the absorbed water in the beginning caused the imbibition of the protoplasm, which was killed by desiccation but the forms were kept only by the lack of water, and were induced to disintegrate as BUCHANAN (1930) pointed out in the aquatic planarians.

The limit of desiccation without any fatal effect may be found to be between 45 per cent and 50 per cent loss of body weight. These data coincide with the fact that the straight line of the change of body weight during desiccation has remarkable discrepancies in these ranges of body weight. Thus we can say that water amounting to about 45 per cent of the body weight (55 per cent of the total water content) is contained in a free state or a reversible state, and that the remaining water, about 45 per cent of the total water, is a combined water, or when this part of the water is removed the desiccated part may be killed and disintegrate if re-imbibition occurs. To test whether the time of exposure to a limited desiccated state has a killing effect, experiments were carried out with smaller animals,

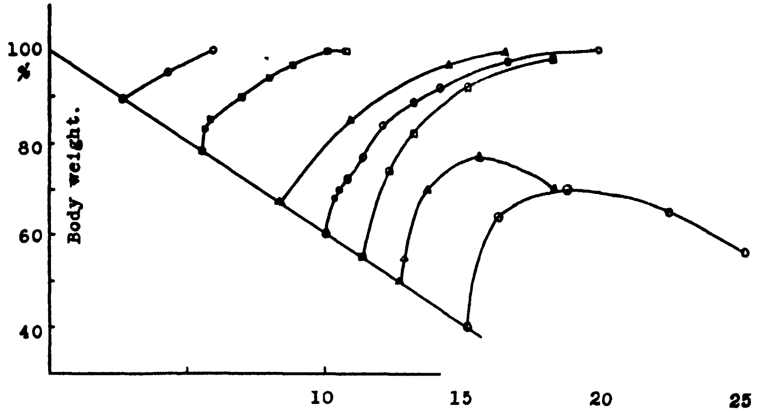


Fig. 8.

Showing the processes of recovery from several stages of desiccation. Ordinate is the body weight in per cent of initial weight. Abscissa is the time in hours. Straight line shows the process of previous desiccation. Each curve shows an individual experiment.

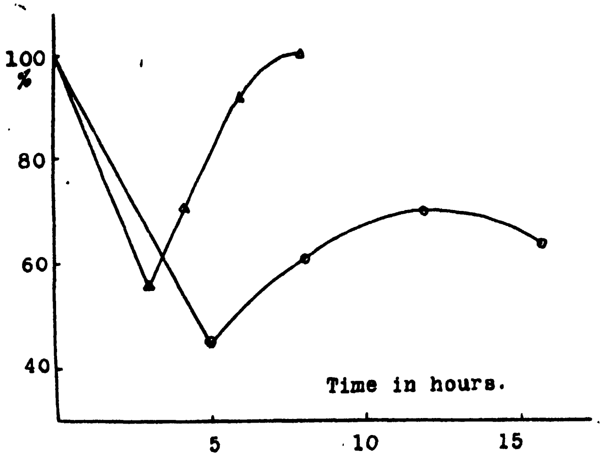


Fig. 9.

Showing the course of recovery from desiccation in an animal of about 0.30 gm.. Straight lines show the processes of desiccation.

in which the time necessary for desiccation to reach a definite percentage of body weight is small. The results are shown in Fig. 9, where it has been proved that the time of desiccation, if that is within the limiting value of desiccation, does not effect the life of the animal. In each case, desiccation which is more than 45 per cent of body weight is fatal to the animal.

The animal endures repeated desiccation after recovery, and recovers again if the water is brought into contact with the body. Of course, in such cases desiccation does not exceed the above-mentioned limit.

GENERAL REMARKS

From the above findings it is clear that land planarians have no mechanism for resisting desiccation, instead the methods of resistance are observed in several forms. When the animal is placed in dry air it remains at rest, rolling up the body and seems to resist desiccation by minimizing the surface exposed to evaporation. This reaction is very remarkable when several animals are kept together in a same vessel, they crowd together with one another making a lump, as has been described by several authors in aquatic planarians.

In the day-time the land planarians rest in a hiding-place, where an almost saturated humidity exists and evaporation from the body surface is extremely minimized and the contacting surfaces supply sufficient water for absorption. When darkness comes and the ground begins to be wet with dew they creep out and seek food. They are protected, also in this case, from evaporation by air of almost saturated humidity, and furthermore loss of water may be regained from wet substances.

The nocturnal nature of these animals may be explained partly by the nature of phototaxis (KAWAGUTI, 1932), but it must be also concerned with these reactions to desiccation.

Even when the animals seem to be saturated with water they are slightly desiccated in the dry day time. It is supposed that the inner swelling pressure is balanced with the elastic tension of the body wall, or of the system as a whole. Therefore, if the body wall of the living system is destroyed the body swells until the swelling pressure of the bodily substances is gone, in short, it is the disintegration of the body, as shown in the experiment of the last section. As the amount of desiccated residue is about 18 per cent of the body weight, the normal state of the body substance can be imagined as a block containing 18 per cent of gelatine, provided with a powerful swelling pressure. According to KUNITZ, (1928), gelatine blocks with concentrations smaller than 10 per cent lose their water in M/1000 acetate buffer pH 4.7, and blocks with concentrations larger than 12 per cent gain water under the same conditions. If one compares to these results the swelling pressure of an 18 per cent gelatine block, balanced with the body wall and the living structure, the swelling pressure may be smaller than was expected at first.

SUMMARY

1. Modes of reaction of land planarians to desiccation have been described.

2. The average water content of land planarians was 82.2 per cent of the initial body weight and it was a little larger at the caudal piece than at the head or middle piece.

3. The area of the body surface or the evaporating surface can be expressed by the linear function of body weight, within a certain limit. The length of the body may be also expressed by linear function of body weight.

4. Desiccation has been studied among several relative humidities at a definite temperature, and at several temperatures in a definite relative humidity. The experiments show that land planarians have no mechanism for resisting desiccation and the rate of evaporation follows clearly the physical law of evaporation. It depends only on the vapour pressure of the saturation deficiency. Temperature does not effect the evaporation within the experiment. Animals smaller than 1 gm., are desiccated more rapidly than larger ones.

5. The rate of desiccation is the same until 50 per cent loss of body weight, but it decreases at further desiccation.

6. Recovery from desiccation was followed. The rate for regaining water is more rapid than the rate of desiccation. Within the limit of 45 per cent loss of body weight, the animal can recover completely from desiccation. Further desiccation causes the disintegration of the body in the recovery, partly or totally, according to the degree of desiccation.

7. Two types of water can be supposed to be in the body of land planarians. One is free or reversible water, the other is bound water. The amount of the latter is 45 per cent of total water contents.

BIBLIOGRAPHY

ADOLPH, E. F., The vapor tension relations of frogs. Biol. Bull. 62, 112-125. (1932)
BUCHANAN, J. W., The nature of disintegration gradients. Jour. Exp. Zool. 57, 455-72. (1930)
BUXTON, P. A., Evaporation from the meal-worm (Tenebrio; Coleoptera) and atmospheric humidity. Proc. Roy. Soc. B. 106, 560-577. (1930)
GRAY, J., The role of water in the evolution of the terrestrial vertebrates. Brit. Jour. Exp. Biol. 6, 26-31. (1928)
HALL, F. G., The vital limit of exsiccation of certain animals. Biol. Bull. 42, 31. (1922)
HATAI, S., Contributions to the physiology of the earthworm. I Sci. Rep. Tohoku Imp. Univer. ser. 4. 1, 1-20. (1924)
KAWAGUTI, S., On the physiology of land planarians. I. Phototaxis, with a note on the significances of the eye spots. Mem. Fac. Sci. Agr., Taihoku Imp, Univ. 7, 15-27. (1932)
KUNITZ, M., Syneresis and swelling of gelatin. Journ. Gen. Physiol. 12, 289-312. (1928)
SHELFORD, V. E., Laboratory and field ecology. p. 252. (1928)
SMITH, v. D. E., and JACKSON, C. M., The changes during desiccation and rehydration in the body and organs of the leopard frog. (Rana pipiens). Biol. Bull. 60, 80-93. (1931)

STUDIES ON THE DISINTEGRATION OF *BRANCHIURA SP.* BY METHYLENE BLUE

I. The effect of Temperature and Thermal destruction

(With 2 Text-Figures)

Siro KAWAGUTI

(Accepted for publication, September 8, 1932)

CONTENTS

1. Introduction 57
2. Material and methods 58
3. Results 61
4. Temperature constants of the phenomenon 64
5. Thermal destruction 66
6. Summary 68
7. Bibliography 69

I. INTRODUCTION

It has been reported by HYMAN (1916) that in *Tubifex tubifex* and *Limnodrilus claparedianus* disintegration by a cytolytic substance begins at the posterior end and proceeds far forward before it takes place in the head region. Dr. T. KAMADA has kindly pointed out to me that *Branchiura sp.* is extremely sensitive to methylene blue, especially at the branchial portion. The present writer intends to interpret this phenomenon and studied its temperature coefficient with a hope to determine

[Mem. of the Fac. of Sci. & Agr., Taihoku Imp. Univ., Formosa, Japan. Vol. VII., No. 1, October, 1932]

whether this is caused by a chemical reaction or a physical reaction. In connection with this study the thermal destruction phenomenon or the effect of high temperature alone on the animal, has also been studied.

I express my best thanks to Dr. KAMADA and also to Prof. HIRASAKA who gave me continuous encouragement during the whole course of the work.

II. MATERIAL AND METHODS

The material used was *Branchiura sp.* (aff. *B. sowerbyi*, Beddard) collected from a ditch around the University. Normally the worms hide their anterior halves in tiny tubes formed almost vertically in the mud bottom. The posterior or branchial portion oscillate to and fro with a definite speed. The gill consists of two rows of fine branchial filaments, one of them at the dorsal and the other at the ventral side of the body.

OKADA (1929) proved that the posterior portion has an important respiratory function. My further researches on the temperature constant of the oscillatory movement of the branchial portion shows its correlation with respiration, as generally considered and actually proved in several other aquatic oligocheates. As has been informed by HATAI (1931), when the oxygen tension of the medium decreases the total length and the frequency of oscillation of the branchial filament increases.

General description

When a *Branchiura* is immersed in a 2/1000% methylene blue solution, it moves convulsively, its branchial filaments and the end of the tail first disintegrate. The body disintegrates gradually toward the anterior region. The whole process of disintegration does not occur continuously from the tail to the head but it seems to be divided into several stages. Portions at the same stage disintegrate approximately at the same time. There are five or six stages. It may be probable that there are some mechanisms for breaking at these points, as in a case of autotomy. Furthermore, these points seems to coincide with the breaking positions of the animal when it is immersed in a strong hypertonic or toxic solution.

The first stage is the beginning of disintegration at the distal end of each branchial filament or at the end of the tail. The second is the hind half of the branchial portion, the third is the total branchial portion, the fourth is the hind half of the total body, and the fifth is at three-fourths the length of the total body. In this last stage disintegration may occur also at the head. Then the death of the animal comes.

These disintegration seems to originate from the vigorous contraction of that part. A decapitated caudal piece disintegrates more slowly than an intact animal. Thus it is probable that this contraction of the part may be associated partly with the nerve centre. Occasionally the animals turn into a moniliform, at the third or fourth stage of disintegration, by the elongation of the body, accompanied by the contraction of the circular muscle, and especially at the region of the septa. This change is a sign of the ante-mortem stage. The deposition of methylene blue in the tissue can be observed before the disintegration occurs. The dead portion may be marked by the color changes of the body from reddish yellow to opaque white. The rupture of the body wall occurs simultanously with, or immediately after, this color change, and the whole structure disintegrates into shapeless granules. While the disintegration proceeds the entire animal is turned into numerous fragments. This is especially most conspicuous in the last stage.

The materials were collected on the day before the experiments and were kept in a glass vessel of adequate size with tap water. Only full-grown animals of approximately equal size were used as the time for disintegration of the first stage varies greatly according to the size. Ten thin-walled hard glass tubes of practically equal size were used as test chambers. The chamber had a cork stopper at the top and its capacity was approximately 3.0 cc.. The test chamber was filled with 2/1000% methylene blue (Grübler), one specimen being immersed in it and was kept in a thermostat at each temperature, the deviation of the temperature of the thermostat being under 0.5°C.

Since the intensity of light effects the velocity of the phenomenon, it is found that the methylene blue partly retains a photodynamical action. This factor was regulated in the measurement by doing the experiments on the table near the north window of the room, from 9 a.m. to 5 p.m. on a cloudy day in March, 1932, avoiding direct light.

For one set of experiments ten animals were used. The time required to induce the first stage of disintegration was measured in each animal. The median of these values was used as the representative of the set. Three sets of experiments were made at the same temperature and the mean value of the medians was adopted as an experimental value. When the experimental temperature was high the mean value of the individual experiments was used as the representative value in place of the median.

When the experiment continued for more than 40 minutes the medium of the test chamber was changed. For the control of this exchange of medium during the experiment, ten animals were put into a beaker of 150 cc. capacity with 100 cc. of the methylene blue solution and observed as to the time for the first stage of disintegration of half of the number. The result was just the same as in the former method.

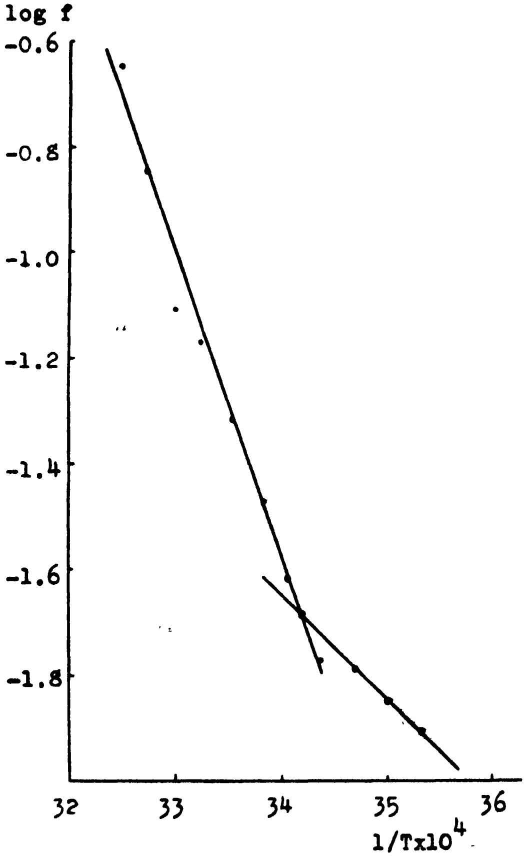


Fig. 1.

Relations between the reciprocals of absolute temperature and the logarithms of velocities of disintegration by methylene blue.

III. RESULTS

The results of the experiments are given in Table I and Fig. 1.

TABLE I

Temperature	Time for disintegration of the first stage		
	Observed	Calculated	
		$A=13.0\times10^3$	$A=4.5\times10^3$
35.0°C	4.4 min.	5.0 min.	
32.5	7.0	7.0	
30.0	12.8	10.0	
27.5	14.9	14.2	
25.0	20.8	20.8	
22.5	30.0	30.0	
20.5	41.5	40.8	
19.2	49.0	49.5	49 min.
17.5	52		53
15.0	62		61
12.5	71		70
12.0	80		80

From these data, the Q_{10} was calculated by SNYDER's formula,

$$Q_{10}=(K_1/K_2)^{\frac{10}{T_1-T_2}}$$

where K_1 or K_2 is the velocity of reaction when the absolute temperature is T_1 or T_2. The actual data are given in Table II.

TABLE II

The Q_{10} of the disintegration of *Branchiura sp.* in methylene blue.

Temperature ranges	Q_{10}
35.0°—30.0°C	8.5
32.5 —27.5	4.4
30.0 —25.0	2.7
27.5 —22.5	4.1
25.0 —20.5	2.0

Temperature ranges	Q_{10}
22.5 —17.5	3.0
20.5 —15.0	2.2
17.5 —12.5	1.9
15.0 —10.0	1.7

The values of Q_{10} for 10.0°–19.2°C correspond to the normal chemical reactions. Q_{10} becomes large at the higher temperature range. These large values of Q_{10} have been frequently reported in the destruction of living substances. It is very interesting to note that the value of Q_{10} diminishes with the decrease of temperature. Such change of the Q_{10} value was already noticed by KANITZ (1915) without any explanation. Frequently the value of Q_{10} increases with the decrease of temperature in a normal biological phenomenon. Among other researches the decrease of the value of Q_{10} by the decrease of the temperature occurred in studying the thermal effect on the killing action of chemicals, the heat coagulation of cells and the effect of butyric acid on the artificial activation of starfish eggs. On the whole, it appears in the destructive thermal effect.

For example, PAULE, BIRSTEIN and REUSS (1910) reported the Q_{10} of the thermal effect of the killing action of N/100 HCl of *Staphylococcus*. The values are as follows. (KANITZ, 1915).

Temperature ranges	Q_{10}
0.4°— 9.2°C	1.53
9.2 —17.9	2.00
17.9 —27.7	2.35
27.7 —37.0	2.67

BROOKS' (1906) data of Q_{10} of the toxic effect of N/16 $CuSO_4$ on *Monilia* are as follows (KANITZ 1915).

Temperature rônges	Q_{10}
5°—10°C	2.67
10 —15	9.0

The values of Q_{10} of the oxygen consumption and the carbon dioxide output by a starved *Potamobius* were as follows (BRUNOW, 1911, cited from KANITZ, 1915).

Temp. ranges	Q_{10} of O_2 consup.	Q_{10} of CO_2 output
7.6°–13.1°C	2.9	2.8
13.1 —17.5	3.2	3.4
17.5 —21.5	4.0	3.8

This result may be interpreted that the respiration during starvation is a disintegration phenomenon in this case. HEYDE (1921) observed a similar change of the Q_{10} on the amount of excretion of the hibernating frog. The values are as follows.

Temperature ranges	Q_{10}
1°—11°C	1.6
11 —21	1.56
21 —31	3.6

LILLIE, R. S. (1917) has adequately interpreted this change of Q_{10}. He obtained the Q_{10} for the activation of starfish eggs by butyric acid as follows.

Temperature intervals	Q_{10} (1st series)	Q_{10} (2nd series)
8°—10°C	1.75	2.0
10 —12	2.2	
12 —14		2.7
14 —16	2.6	3.55
16 —18	4.65	
18 —20		5.0
20 —22		6.4
22 —24	5.0	9.5
24 —26	11.6	10.5
26 —28		32.

These results agree with mine and his explanations of this change of Q_{10} also may be applied.

In the range of 10°C–25°C, the Q_{10} was 1.9–3.0, which indicates that the disintegration of *Branchiura* by methylene blue may be induced by the normal chemical reactions, that is, the effect of methylene blue on the protoplasm. At the temperatures above 25°C., there may be another additional factor—probably the direct influence of the high temperature on disintegration. The control experiments show that the temperature has no direct influence on disintegration but it can induce some changes in the physico-chemical natures of the animal, for example, the changes in the permeability of the surface for methylene blue, the changes of the oxydation reduction system and the colloidal nature of the animal, etc. Thus the reaction is accelerated at a higher rate than is expected from the influence of temperatures upon the velocity of the reaction alone. Whatever the explanation may be, it is interesting to note that the disintegration phenomena exhibit a rise in rates with a rise of temperature similar to that for other destruction phenomena.

IV. TEMPERATURE CONSTANTS OF THE PHENOMENON

It may be reasonable to replace the temperature coefficient, q, or the temperature characteristics, μ, of ARRHENIUS' formula

$$\ln(K_2/K_1)=\frac{q}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)$$

by another constant A, being equal to q/R. Because, as has been adequately discussed by YAMAMOTO, 1931, in biological reactions it is doubtful whether the expression of q or μ in calories has any meaning and there is no need to separate two constants, q and R.

Furthermore, recently SNYDER (1931) pointed out that the q is one quantum when the formula is induced from photochemical reactions and it is five quantum from the thermochemical standpoint. I have some reasons for believing that this phenomenon of disintegration may be related partly to the photochemical reaction of methylene blue.

The constant A of the formula,

$$\ln(K_2/K_1)=A\left(\frac{1}{T_1}-\frac{1}{T_2}\right)$$

where K_1 and K_2 are the frequencies of the reaction at absolute temperature T_1 and T_2, was calculated from the data of Table I. There was a "break" at 19.2°C. The data were divided into two groups and A for each group was calculated separately. The straight lines, corresponding to these values of A, are drawn in Fig. 1. The data calculated for the time for the first stage of disintegration by using these data of A were compared with the observed data in Table 1 and seem to fit fairly well.

The value of A was $13.0 \times 10^3 \pm 0.2 \times 10^3$ for the range of 32.5°–19.2°C, and it was 4.5×10^3 for the range of 19°C–10°C. Such values of A were obtained for the rates of the development and the disintegration phenomenon.

Krogh's (1914) data for the velocity of pupal development of *Tenebrio* gave $A = 5 \times 10^3$, 13.5×10^3 with a break at 22°C. Temperature constant A for the velocity of the development of *Drosophila* were 5×10^3, 13.5×10^3 with a break at 20°C (Crozier, 1924–25). Gray's (1928) data on the development of *Salmo* also gave these values.

The higher value of A of these cases is limited in the range of low temperatures. Such an example of A at a range above 20°C is very rare. We can find it in the heat destruction phenomenon, for example, Ayres' (1916) data on the killing effect of high temperature on *Ceramium* was 13.8×10^3. (Brown and Crozier, 1927).

Any adequate explanations of the phenomenon, however, could be given by these data, it is only a secondary coincidence. The other instances must be secured in the other phenomena. The measurement of the velocity of the enzymic reduction of soluble Prussian blue, by Harris and Creghton 1912, yielded $A = 4.8 \times 10^3$ (Crozier, '24–25). The A of Amberson's figure (1921–22) for the oxidations (dehydrogenation) of luciferin by luciferase with the production of light was approximately 12.5×10^3, and there is reason to believe that the reaction might be controlled by the dehydrogenation. Another example is given in the data of Hartridge and Roughton 1923, on the velocity of the oxygenation of haemoglobin, which gives $A = 12.8 \times 10^3$. (Crozier, '24–25).

From these data it may be supposed that the controlling reaction of the destruction phenomenon of *Branchiura* by methylene blue is dehydrogenation. In other words, the methylene blue acts as a dehydrogenating enzyme in this case. This is quite reasonable according to the nature of methylene blue.

It must be remembered that the temperature constant A of the higher temperature range is larger than that of the lower temperature range. This is a special case, as described in the former section, according to Q_{10} values. Because A may be expressed by $A=0.23 \times T_1T_2 . \log Q_{10}$, and in the range of temperatures, where the biological reactions are going on, $T_1.T_2$ may be considered as a constant (BELEHRADEK, 1928). Then the peculiarity of Q_{10} may be also the peculiarity of A.

V. THERMAL DESTRUCTION

Although the temperature did not directly effect the disintegration by methylene blue, as shown in the previous section, it may be reasonable to note the thermal destruction. The experiment was done in a beaker of 200 cc. capacity and containing about 100 cc. of tap water. The material was kept before the experiment in a starved condition at 28°C–30°C. The temperature of the test medium was regulated to the desired one. Six worms were used in one experiment and the time for

TABLE III

The thermal destruction of *Branchiura sp.*

Temperature	Time for death in seconds	
	Observed	Calculated, $A=9.4 \times 10^4$
49.0°C	2.7	1.3
48.0	4.4	3.2
47.0	8.5	8.2
46.0	24	21
45,0	59	54
44.0	139	140
43.0	304	357
42.0	1200	912
41.0	2340	2340

death of half the number was determined. As the indication of death, the stopping of the motion of the mouth part was observed. Four or five tests were made in each temperature. The mean values are given in Table III and the relations between the absolute temperature and the logarithm of the velocity of death are plotted in Fig. 2.

These data yield the temperature constant A of ARRHENIUS' equation $9.4 \times 10^4 \pm 0.1 \times 10^4$, (calculated in the range of temperature at 47°-41°). The fitness of the equation is fairly good, as in Table III. The deviations of the observed value from the calculated value at the higher temperatures may be probably caused by the fact that the materials were kept in tap water at 30°C and were put in the test water. There must be two factors for the velocity of the effect of high temperature, one is that velocity of the change of temperature of the whole animal body and the other is the degree of the temperature. The former factor may be equal in each case within the range of our experiment. Then this factor may greatly effect when the second factor becomes small, that is, when the temperature is high. These high values of A have been reported by several authors in the thermal destruction phenomenon of living matter. It can be concluded

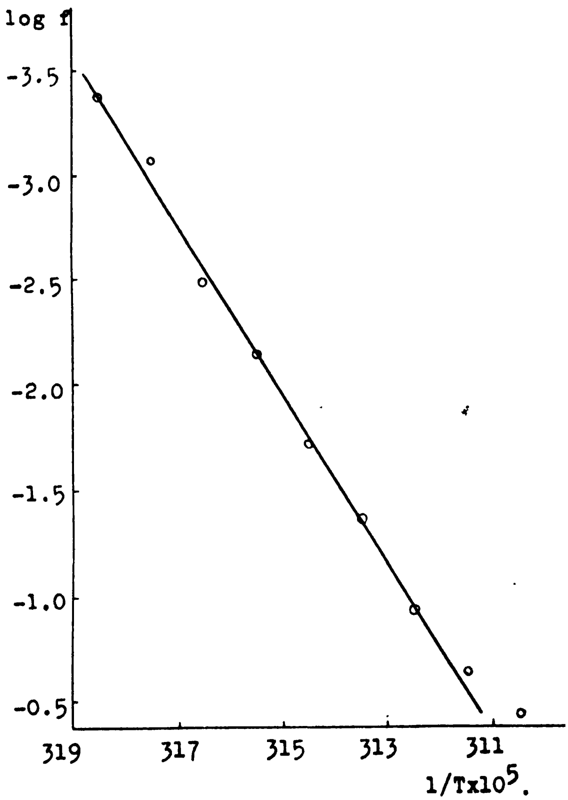


Fig. 2.

Relations between the reciprocals of absolute temperature and the logarithms of reciprocal of the time of thermal destruction of *Branchiura sp.*

that the thermal destruction of *Branchiura sp.* may be controlled by the coagulation of protein or similar substances. It is very interesting to know that the temperature coefficient of the thermal destruction is quite different from that of the destruction by methylene blue.

HATAI 1929 reported an interesting experiment on the effect of high temperature on the *Branchiura sp.* and concluded that its resistance to high temperature is much higher than that of the terrestrial earthworms. He maintains that the worm keeps its irritability until 47°C. But, in my case half the number of worms were killed within 10 seconds at the same temperature. Furthermore, the temperature in which the specimen being kept was probably near 19°C in the case of HATAI's experiment, and it was 28–30°C in my case. This significant differences of the resistance to a high temperature probably was caused by the different methods or material.

SUMMARY

1. The disintegration phenomenon of *Branchiura sp.* by methylene blue is described.

2. The Q_{10} of this phenomenon shows the normal chemical reactions which induce the phenomenon within the limit of 25°–10°C, and in a higher temperature Q_{10} becomes larger and indicates that there is an effect from heat.

3. The case in which Q_{10} diminishes its value with the decreasing temperature is discussed. It is considered to be a case of the destruction phenomenon of living matter.

4. The values of A of ARRHENIUS' formula was calculated and obtained 4.5×10^3 for below 19.2°C and $13.0 \times 10^3 \pm 0.2 \times 10^3$ for the higher temperatures. From these data of A it has been supposed that the phenomenon may be controlled by dehydrogenation, which might be catalyzed by methylene blue.

5. The value of A of the thermal destruction with high temperature (41°–49°C) was $9.4 \times 10^4 \pm 0.1 \times 10^4$. This value shows that the destruction by methylene blue is quite different from thermal destruction.

BIBLIOGRAPHY

Běleheádek, J., Protoplasma 5, 311–8. (1928)
Brown, L. A., and Crozier, W. J., Jour. Gen. Physiol. 11, 25–35. (1927)
Crozier, W. J., Jour. Gen. Physiol. 7, 189–216. (1924–25)
Gray, J., Brit. Jour. Exp. Biol. 6. 125–30. (1928)
Hatai, S., Japanese Jour. Zool. 1, 1–22. (1922)
Hatai, S., The Study on Earthworms. (in Japanese) 82–85. (1931)
Heyde, v. D., Biol. Bull. 41, 249. (1921)
Hyman, L. H., Jour. Exp. Zool. 20, 99. (1916)
Kanitz, A., Temperatur und Lebensvorgänge. (1915)
Lillie, R. S., Biol. Bull. 32. 131–58. (1917)
Okada, T., Dôbutugaku Zassi. 41, 416–7. (1929)
Snyder, C. D., Science, 74. 443–9. (1931)
Yamamoto, T., Jour. Fac. Science. Imp. Univ. Tokyo. IV, 2, 381–8. (1931)

ZUR BIOLOGIE DES ZOOPLANKTONS IM ZITUGETUTAN (SEE CANDIDIUS).

(Studien über die Süsswasser-Fauna Formosas II.)

ERRATA

Page.	Line	Read	For
76	27	Zugleich	Zugleicn.
84 85 124	26 2 28	pelagischen Zone	Pelagischen zone.
86	Fig. 4, 13	*leuchtenbergianum*	*teuchtenbergianum.*
112	22	*Diaptomus birulai*	Diaptomus birulai
124	27	,	;

... ... 88
1. Dinoflagellata.
Peridinium playfairi 89
2. Nematoda (eine unbestimmte Species). 90
3. Rotatoria.
Schizocerca diversicornis. 91
Rattulus capucinus. 93
Diurella stylata. 94
Triarthra longiseta. 96
Pedalion mirum. 99
Ploesoma hudsoni. 100
Rattulus cylindricus. 101

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VII, No. 2. July, 1933.]

Anuraea aculeata var. *valga*. 102
Brachionus forficula var. *laevis*. 104

4. Cladocera.

Bosmina longirostris. 106
Chydorus sphaericus. 111

5. Copepoda.

Diaptomus birulai. 112
Mesocyclops thermocyclopoides.... 119
Eucyclops prasinus candidiusi. 124

6. Ostracoda.

Cypria javana. 126

7. Diptera.

Corethra-Larven. 129
C, Anhang. Einfluss eines Sturmes auf die Biocoenose des Sees.... 135
Literaturverzeichnis. 138

EINLEITUNG.

Der Zitugetutan (See Candidius) liegt etwa in der Mitte von Formosa und repräsentiert ein typisches tropisches Binnengewasser, welches für den Hydrobiologen von grösstem Interesse ist.

Der See ist durch eine von SO nach NW verlaufende Landzunge und auch noch eine kleine auf derselben Achse liegende Insel in zwei Becken von ungleicher Grösse gegliedert, nämlich in ein grösseres, das "Zittan" genannt wird und sich von der Vereinigungsstelle aus mit seiner Langsachse gegen Osten ausdehnt, und in ein kleineres Becken, das den Namen "Gettan" trägt und sich mit seiner Langsachse etwa nach Süden erstreckt.

Der einzige Abfluss verlasst den See an der Vereinigungsstelle der beiden Becken im Westen.

Der Darstellung von Forel (1901) für die Alterstufen der Seen folgend, ist unser See als ein schon von der Phase des Reifealters zu der des Greisenalters übergehender See zu bezeichnen, indem eine erstaunliche Schlammablagerung überall in seinem Becken vorherrscht und auch eine auffällige Bildung von Sümpfen besteht, welche besonders in der Halsregion des Sees wohl entwickelt sind.

Der Bodenschlamm besteht aus einem meist autochthon gebildeten Sapropel, da der See keine nennenswerten Zuflüsse oder Quellen besitzt. Doch muss hier betont werden, dass der reichliche, schwebende Detritus in der Tiefe sowohl die deutliche Unterscheidung der Wasserschichte von dem echten Boden, als auch die eingehende quantitative Untersuchung der Planktonorganismen in der Wasserschichte unterhalb einer Tiefe von ca. 3 m sehr erschwert.

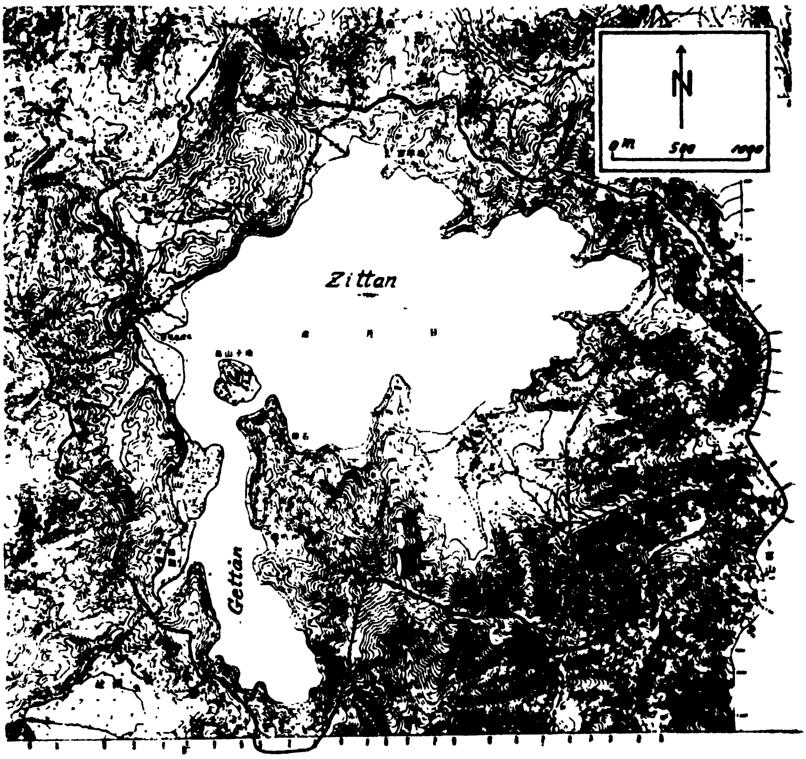


Fig. 1.
Karte des See Candidius (Zitugetutan), den Umriss und das Einzugsgebiet des Sees zeigend.

Die morphometrischen Werte unseres Sees sind im folgenden zusammengestellt. Alle Flächeninhalte wurden mit Hilfe des Planimeters aus den Landkarten von 1 : 25,000 und 1 : 10,000* gemessen.

---

* Diese letztere Karte wurde von der Elektrizitäts-Gesellschaft von Taiwan für ihre besonderen Zwecke ausgearbeitet.

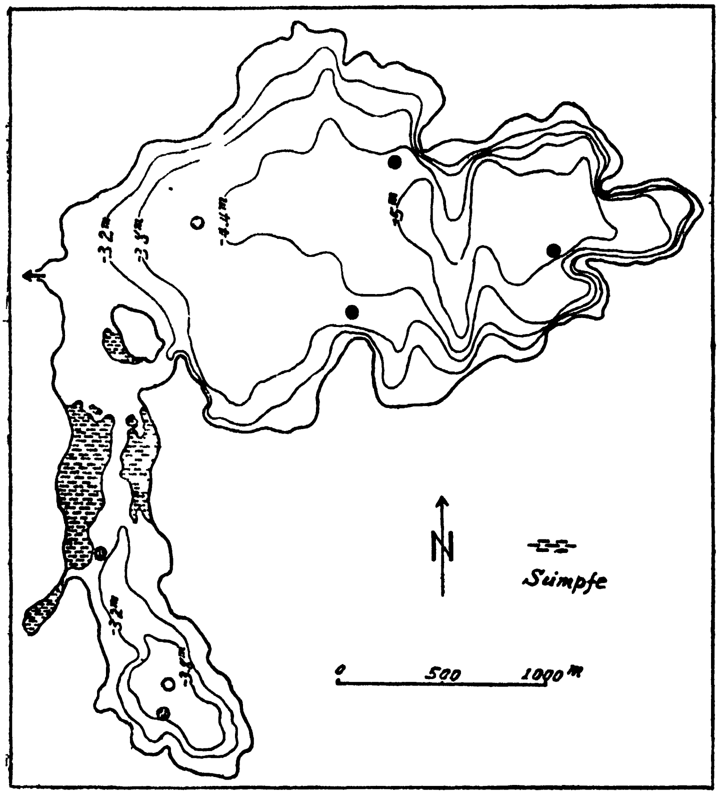


Fig. 2.

Karte des See Candidius, hauptsachlich die Isobathenlinien zeigend. ○ Fangstation fur biologische Studien. ● Chemisch-physikalische Untersuchungsstationen.

Mittlere Höhe der Seeoberflache ü. d. M.		726.8 m
Einzugsgebiet		17.031 km²
Flacheninhalt des Sees samt Insel und Sümpfen... ...		5.563 „
Flächeninhalt der Insel		0.050 „
Insulierung		0.9 %
Flächeninhalt der Sümpfe		0.236 km²
Verhältnis der Sümpfe zum See		4.24 %
Areal des echten Wasserspiegels	5.277 km²	
„ der 3.2 m-Isobathenfläche	3.539 „	67.1 %
„ „ 3.8 „ „	2.792 „	52.9 „

Areal der 4.4 „ „ . ... 1.400 „ 26.5 „
„ „ 5.0 „ „ ... ... 0.436 „ 8.5 „

Das Volumen der Tiefenstufe zwischen je zwei Isobathenflächen wurde nach der Formel $h.\frac{A+B+\sqrt{AB}}{3}$ berechnet.

Tiefenstufe m	Vol. d. Tiefenstufen Mill. cbm
0 -3.2	14.013
3.2-3.8	1.895
3.8-4.4	1.193
4.4-5.0	0.524
	17.625

Länge der Uferlinie	17.5 km
Uferentwickelung $\frac{l}{2\sqrt{G\pi}}$	2.15
Mittlere Tiefe	3.34 m

Vorstehende Zahlen geben die gegenwärtige Gestaltung des See Candidius. Da er aber als Sammelbecken für die wasserelektrische Kraftstation der Elektrizitäts-Gesellschaft von Taiwan ausersehen ist, soll sich der Wasserspiegel, mit der in kürzerer Zukunft zu erwartenden Vollendung der Bauten, ca. 25 m über die gegenwärtige Seeoberfläche erheben, was durch die Abdämmung des jetzigen Abflusses und durch Hereinziehung der Wässer des Dakusui-Flusses erreicht werden soll.

Es ist vorauszusehen, dass eine solche weitgehende Veränderung der Lebensbedingungen einen ebenso bedeutenden Wechsel in der Biocoenose des Sees mit sich bringen wird.

Der Zweck der vorliegenden Untersuchungen besteht also darin, die Biocoenose der Planktonorganismen und die Lebensbedingungen in der Gegenwart klar zu machen, und zugleich eine Grundlage für die Verfolgung des Ablaufs der Veränderungen in der Zukunft zu legen.

Hier sei es mir gestattet, Herrn Prof. K. HIRASAKA, unter dessen Leitung die vorliegende Arbeit entstanden ist, meinen wärmsten Dank für seine jederzeit bereite Unterstützung auszusprechen.

I. METHODIK.

Die Untersuchungen wurden in der Zeit vom März 1929 bis zum Januar 1930 ausgeführt.

Die Proben in jedem einzelnen Untersuchungsmonat wurden ohne Ausnahme an einem und demselben Orte, welcher in Fig. 2 mit der Marke ○ gekennzeichnet ist, entnommen, und bestehen, mit Ausschluss der Monate Juli und August, aus je einer Serie, welche an zwei aufeinanderfolgenden Tagen gesammelt wurde. Es wurden nämlich stundenweise Proben von 5 h Morgens bis 12 h Mittags am ersten Tage, und von 13 h bis 21 h Abends am nächsten Tage entnommen, um die vertikale Verteilung der einzelnen Planktonorganismen im Laufe des Tages festzustellen. Ferner wurden zu diesem Zwecke je 3 Proben, möglichst in derselben Stunde, und beziehentlich aus der Tiefe von 0, 1.5 und 2.5 m entnommen. In unserem See ist die Wasserschichte von 0-2.5 m der maximale Bereich, in welchem wir ohne Störung durch den reichlich schwebenden Detritus das genauere quantitative Studium der Planktonorganismen ausführen konnten.

Für die Probeentnahmen verwendeten wir einen Wasserschöpfer nach Kitahara (Volumen : 1 L.).

Die entnommenen Wasserproben (je 5 L.) wurden erst durch ein halb ins Wasser eingehängtes Planktonnetz (Müller-Gaze Nr. 20) filtriert, dann mit der nötigen Menge des filtrierten Seewassers sorgfältig in einer Glasflasche abgespült und sofort mit Formol versetzt.

Die quantitative Untersuchung der Planktonorganismen wurde nach dem Zurückbringen der Proben im Laboratorium unserer Universität ausgeführt; dabei wurden in jeder Probe alle Organismen durchgezählt.

Zugleicn wurden auch die Temperaturschwankungen von Luft und Wasser an der Seeoberfläche berücksichtigt.

Was die graphische Darstellung des Auftretens der Planktonorganismen betrifft, so erschien es im allgemeinen vorteilhafter, nicht die Lohmann'schen Kurven, sondern vielmehr die tatsächlich für die einzelnen Arten beobachteten Individuenzahlen pro 1 L. Seewasser einzusetzen, weil in dieser Weise die zeitlichen und örtlichen Verteilungsverhältnisse viel klarer und deutlicher in Erscheinung treten. Diese Methode wurde in allen Fällen befolgt, soweit keine anderweitige Erklärung beigefügt ist.

Die chemisch-physikalische Untersuchung des Seewassers wurde zweimal, im Mai und Oktober des Jahres 1929, ausgeführt.

II. CHEMISCH-PHYSIKALISCHE VERHÄLTNISSE.

A. CHEMISMUS.

Da unser See keine auffälligen Zuflüsse besitzt, so scheinen die reichlich vorhandenen organischen Stoffe meist im See autochthon zu entstehen.

Der Chemismus unseres Sees ist, wegen seiner starken Schlammablagerung, schon Gegenstand früherer Untersuchungen gewesen, von welchen die der Herren Dr. K. SHIBUYA und K. HIGUCHI (1930) besonders eingehend ist. Älteren Datums ist die nähere Untersuchung des Chemismus des Seewassers von Dr. K. YAMAGUCHI und R. KASUYA (1919), welche auf Ansuchen der Elektrizitäts-Gesellschaft von Taiwan ausgeführt, bisher aber nicht veröffentlicht* wurde. Die in folgender Tabelle zusammengestellten Analysenresultate des Seewassers sind letzterer Arbeit entnommen.

Tabelle 1.

Trockenrückstand	mg/L	59.00
Cl	„	1.42
SO_3	„	14.61
N_2O_5	„	2.40
P_2O_5	„	Spur
Freie u. halbgebundene CO_2	„	27.21
Gesamte CO_2	„	47.72
SiO_2	„	5.90
Fe_2O_3	„	0.40
Al_2O_3	„	1.30
CaO	„	3.10
MgO	„	1.78
K_2O	„	Spur
Na_2O	„	14.73
$KMnO_4$-Verbrauch	„	12.64

---

* Herr M. Minami, leitender Direktor der Elektrizitäts-Gesellschaft von Taiwan, hatte die Güte, mir Einsicht in diese Arbeit zu gewähren, und die Veröffentlichung der Tabelle zu genehmigen, wofür ich ihm zu wärmstem Dank verpflichtet bin.

Parallel mit unseren biologischen Untersuchungen wurden die chemisch-physikalischen Untersuchungen von Herrn S. ÔNO (Biochemiches Laboratorium unserer Universität) revidiert.

Die Probeentnahmen für letzteren Zweck wurden zweimal im Jahre 1929, einmal am 25. Mai, das zweite Mal am 23. Oktober, vorgenommen. Beide Serien für die chemische Analyse stammen aus 6 bestimmten Stationen (in Fig. 2 mit dem Zeichen ● versehen). Leider konnten diese Arbeiten nur das Oberflächenwasser berücksichtigen, nicht aber die tieferen Schichten.

Die auffälligeren quantitativen Unterschiede zwischen diesen beiden Serien betreffen, wie folgende Tabelle zeigt, den NH_3-Gehalt, die Oxydierbarkeit, und den Trockenrückstand.

Tabelle 2.

Tabellarische Darstellung der chemisch-physikalischen Beschaffenheit des oberflächlichen Seewassers.

Datum		25. V, 1929	23. X, 1929
Wassertemperatur	°C	26.0–27.0	24.0–24.5
pH		6.4– 6.8	7.0
O_2-Gehalt	mg/L.	10.4	12.4
NH_3-Gehalt	„	0.0207	0.0708
Organischer N	„	0.0304	0.0263
Trockenrückstand	„	51.7	39.1
Oxydierbarkeit (KMnO$_4$-Verbrauch)	„	17.000	23.794
Härte i. deutsch. Gr.		2.6	—

B. THERMIK.

Es ist unbestritten, dass die thermischen Verhältnisse einen sehr wichtigen Faktor für die Biocoënose der Seen darstellen.

Wie schon erwähnt, ist der See Candidius so seicht, dass Veränderungen der Lichtintensität rasch auf die Wasserschichten sowohl der Oberfläche als auch der Tiefe ihren Einfluss ausüben, und dass demnach in ihm eine deutliche thermische Schichtung zu keiner Jahreszeit festzustellen ist. In dieser Hinsicht ist also unser See als homotherm zu bezeichnen.

Die von uns in den einzelnen Beobachtungsmonaten festgestellten Durchschnittstemperaturen sind in der folgenden Tabelle zusammengestellt.

Tabelle 3.

Monatliche Durchschnittstemperaturen des Wassers im See Candidius (III, 1929—I, 1930). Temperatur in °C.

Monate / Tiefe m	III 1929	V	VII	VIII	IX	X	XI	I 1930
0	20.6	26.6	28.5	24.5	28.7	24.2	21.8	19.7
3	20.5	26.5	28.3	24.6	28.4	—	21.9	11.9

Betrachtet man die Tabelle, so fällt es sofort auf, dass die extreme Abkühlung des Seewassers in den Januar 1930, und die höchste Erwärmung in den September 1929 fällt. Doch machten wir die höchste Einzelmessung der Wassertemperatur, 29,5°C, an der Oberfläche am 22. VII, 1929 und die niederste, 18,4°C, in der Tiefe von 3 m am 26. I, 1930. Die temporäre Abkühlung im August, welche ungeachtet des Hochsommers sehr ausgeprägt ist, beruht ausschliesslich auf den Stürmen, begleitet von heftigem Regen, von denen damals die Gegend heimgesucht wurde. Da jedoch diese Stürme (Taifune) regelmässig jedes Jahr um diese Zeit wiederkehren, ist ein solcher vorübergehender Temperaturabsturz sehr wahrscheinlich ein regelmässiges Ereignis.

Wir wollen nun an die Betrachtung der täglichen Schwankungen der oberflächlichen Wassertemperatur im Laufe des Beobachtungsjahres herangehen, und dabei zugleich die der Lufttemperatur berücksichtigen.

Wie oben erwähnt, hat der See Candidius weder regelmässige bedeutendere Zuflüsse noch Quellen, und demnach sind die täglichen Schwankungen der Wassertemperatur bei ruhigem Wetter hauptsächlich auf die Beleuchtungsintensität zurückzuführen.

Diese Verhältnisse seien zunächst mit Bezug auf die Lufttemperatur dargestellt.

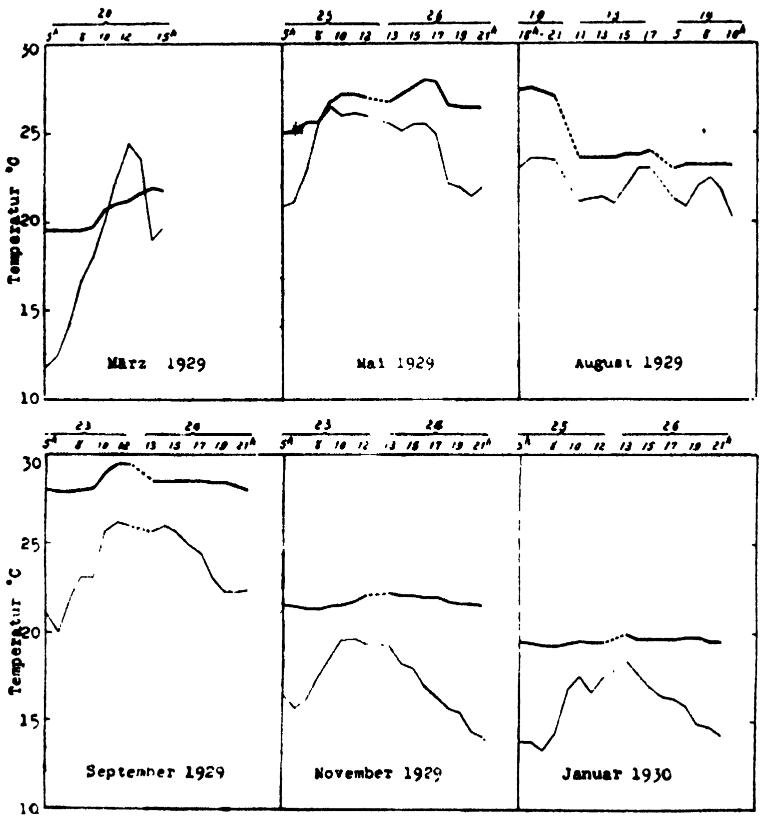


Fig. 3.

Tägliche Schwankungen der Wasser- und Lufttemperatur.

—— Wasser-, —— Lufttemperatur.

Wie aus den Figuren hervorgeht, erreicht die Wassertemperatur im allgemeinen am Frühmorgen, etwa um Sonnenaufgang, den niedersten Grad (siehe besonders die Figuren für September, November und Januar) und steigt dann ganz entsprechend der ziemlich plötzlich steigenden Lufttemperatur gegen Mittag allmählich an, um im Laufe des Nachmittags wieder abzusinken; sie weist also etwa am Mittag je nach der Amplitude der Bewegung der Lufttemperatur einen manchmal auffallenden, manchmal schwach erkennbaren Sprung auf.

In der Figur für den März ist der anfängliche Temperaturunterschied zwischen Luft und Wasser am Frühmorgen ausnehmend gross. Im Laufe des Vormittags jedoch steigt die Lufttemperatur viel rascher an als die Wassertemperatur, und gegen Mittag kommt es zu einer Kreuzung der beiden Kurven. Für einige Zeit übertrifft die Lufttemperatur die Wassertemperatur, sinkt aber bald wieder unter die letztere.

Im Mai berühren sich die beiden Kurven am Mittag, dabei ist aber der Abstand der beiden Temperaturen am Frühmorgen sehr verkürzt.

Dieser Umstand, dass die beiden täglichen Temperaturkurven in dieser Jahreszeit sich kreuzen oder berühren, ist insofern von grossem Interesse, als daraus unzweifelhaft hervorgeht, dass die ausgeprägte steigende Erwärmung des Seewassers in die Frühlingsmonate fällt.

In den folgenden Monaten tritt eine Änderung der Verhältnisse ein, und im weiteren Verlaufe des Jahres liegen die beiden Kurven vollkommen getrennt voneinander, d. h. die Lufttemperatur ist stets niedriger als die Wassertemperatur.

Die thermischen Verhältnisse im August wollen wir hier nicht näher behandeln, da sie besondere Erscheinungen darbieten, welche später eingehend erörtert werden sollen.

Ungeachtet der hohen Wassertemperatur wurde ein grosser Unterschied zwischen Wasser- und Lufttemperatur von uns am 23. September 1929 beobachtet, und Herr S. Ôno mass im Oktober 24.2°C als Wasser- und 21.5°C als Lufttemperatur; somit dürfte Ende September als Beginn der Abkühlungsperiode zu bezeichnen sein.

In den weiteren Monaten, bis zum Januar des folgenden Jahres, erfolgt sodann die stufenweise Abkühlung des Seewassers im völligen Einklang mit der fallenden Lufttemperatur. Ferner ist zu bemerken, dass die Wassertemperatur im Spätherbst und in den Wintermonaten innerhalb des Tages nur geringe Schwankungen aufweist und als mehr oder weniger konstant bezeichnet werden kann.

III. BIOLOGISCHE VERHÄLTNISSE.

A. ALLGEMEINER TEIL:

Zusammensetzung des Zooplanktons.

Der Zitugetutan ist ein eutropher See, charakterisiert durch das reichliche Auftreten von Planktophyten aus den Familien Chroococcaceae, Zygnemaceae, Botryococcaceae usw.

Die Identifizierung des Netzplanktons bereitete mir sehr grosse Schwierigkeiten, weil bis jetzt noch keine eingehenderen Untersuchungen uber die Planktonorganismen der Susswasser Formosa's unternommen worden sind. Nur uber die Cyclopidenfauna und einen parasitischen Copepoden (*Ergasilus japonicus* HARADA) hat Verfasser dieses vor einiger Zeit berichtet.

Die folgende Übersicht enthalt mehr als 30 Arten, welche im Zooplankton teils hauptsachlich der Profundalregion, teils nur der litoralen Zone vorkommen.

Dinoflagellata:

Es kommt nur *Peridinium playfairi* LINDEMANN 1931 in unserem See vor, bildet aber infolge seines Auftretens in erstaunlicher Anzahl das ganze Jahr hindurch eine der Leitformen.

Nematoda:

Eine unbestimmte Nematoden-Species ist in den Schöpfefangen aller Jahreszeiten stetig, aber immer sehr sparlich zu finden.

Rotatoria:

Sehr viele Arten von Rotatorien kommen vor, welche nach der Periodizitat ihres Auftretens folgendermassen eingeteilt werden.

Monozyklischer Typus;

Rattulus capucinus (WIERZ. u. ZACHAR.) 1893.
Diurella stylata EYFERTH 1878.
Schizocerca diversicornis DADAY 1855.
Triarthra longiseta EHRENBERG 1835.

Pedalion mirum HUDSON 1871.
Ploesoma hudsoni (IMHOF) 1891.

Dizyklischer Typus:

Rattulus cylindricus (IMHOF) 1891.
Anuraea aculeata var. valga (EHRBG.) 1838.

Polyzyklischer Typus:

Brachionus forficula var. *laevis* APSTEIN 1907.

Während die zeitliche Lage der periodischen maximalen Massenentfaltung für die eben aufgezählten Rotatorien je nach der Species verschieden ist, sind sie fast alle während dieser Periode als Leitformen zu bezeichen; eine Ausnahme bilden *R. capucinus* und *P. hudsoni*, deren Bevölkerungsdichte selbst im Maximum sehr gering ist.

Ausser diesen Arten ist noch das sehr spärliche Auftreten von *Polyarthra platyptera* EHRBG. und *Anuraea cochlearis* GOSSE zu erwähnen.

Crustacea:

Die Artenzahl der in unserem See als Plankter auftretenden Crustaceen ist vergleichsweise sehr reichlich, indem nachstehende 18 Arten im Plankton vertreten sind:

Cladocera:

Diaphanosoma brachyurum var. *leuchtenbergianum* LILLJEBORG 1900.
Bosmina longirostris (MÜLLER) 1785.
Macrothrix rosea (JURINE) 1820.
Chydorus sphaericus (MÜLLER) 1785.
Acroperus harpae (BAIRD) 1835.
Alona quadrangularis (MÜLLER) 1785.
Pleuroxus hamulatus BIRGE 1910.

Copepoda:

Diaptomus birulai RYLOV 1921.
Eucyclops euacanthus (SARS) 1909.
E. serrulatus (FISCHER) 1851.
E. (Tropocyclops) prasinus candidiusi HARADA 1931.

Macrocyclops albidus oligolasius KIEFER 1927,
Cyclops (*Microcyclops*) *varicans* SARS 1863.
Mesocyclops leuckarti f. *typica* (CLAUS) 1857.
M. thermocyclopoides HARADA 1931.
Canthocamptiden (eine unbestimmte Species).
Ergasilus japonicus HARADA 1931.

Ostracoda:

Cypria javana MÜLLER 1906.

Von diesen Crustaceen-Arten sind im Plankton des Pelagials nur 7 Arten vertreten: *D. brachyurum* var. *leuchtenbergianum*, *B. longirostris*, *Ch. sphaericus*, *D. birulai*, *M. thermocyclopoides*, *E. prasinus candidiusi* und *E. japonicus* (freilebende Stadien). Nur *D. brachyurum leuchtenbergianum* und *E. japonicus* sind in ihrem Auftreten sehr spärlich, die anderen dagegen erscheinen entweder nur in der Periode ihrer maximalen Massenentfaltung oder aber das ganze Jahr hindurch als dominante Formen.

C. javana bildet auch die Leitform der Bodenfauna, indem sie das ganze Jahr hindurch in beträchtlieher Menge vorkommt.

Die übrigen Arten gehören meistens zur Fauna der Uferzone, können aber ausnahmsweise auch im Pelagial vorkommen. Ein solches Vorkommen scheint jedoch eine temporäre Erscheinung zu sein, verursacht durch aussergewöhnliche Umstände, wie ausnehmend starken Regenfall. Das in dem den See umgebenden Einzugsgebiet gefallene Regenwasser ergiesst sich in gewaltiger Menge in den See und verursacht nicht nur eine Erhöhung des Wasserstandes sondern auch eine Braunfärbung des Seewassers in der Pelagischen zone, woauf wir später nochmals zurückkommen; damit mag das Eindringen gewisser Uferbewohner in das Pelagial einwandfrei zu erklären sein.

Diptera:

In der Bodenfauna bilden *Corethra*-Larven eine wichtige Komponente der Biocoenosen unseres Sees.

Um dieses Kapitel zu schliessen, wiederholen wir, dass das Zooplankton unseres Sees mehr als 30 Arten umfasst, wenn wir das ganze

Jahr in seiner Gesamtheit betrachten. Die Zahl der Arten, welche mehr oder weniger regelmässig in der Pelagischen zone vorkommen, beträgt etwa 20.

Unsere nächste Aufgabe ist eine Betrachtung der biocoenotischen Veränderungen innerhalb des Zooplanktons, welche im Verlauf des Untersuchungsjahres beobachtet wurden.

Die in nachstehendem Diagramm (Fig. 4) aufgeführten 20 Arten von Planktern bestehen aus Rotatorien : 9, Crustaceen : 8, Dinoflagellaten, Nematoden und Dipteren : je 1 Art.

Von diesen 20 Arten treten 11 (Rotatorien : 3, Crustaceen : 5, Dinoflagellaten, Nematoden und Dipteren : je 1 Art) perennierend auf, betragen somit 55% der gesamten Planktonorganismen.

Die anderen 9 Arten, also 45% der Gesamtzahl, sind nicht perennierend und haben selbstverständlich alle eine, teils lange, teils kurze Ruheperiode, deren Lage in Bezug auf die Monate aber, wie später im speziellen Teil näher dargestellt werden soll, für die einzelnen Species verschieden ist.

Nur bei *Ergasilus japonicus* verhält sich die Sache verschieden. Hier scheint es uns, dass die zeitliche Unterbrechung des Auftretens zwischen August und November die Periode des Biotopwechsels anzeigt. Bei dieser Art sind nämlich nur die Jungen und die Männchen freilebend ; die geschlechtsreifen Weibchen dagegen leben als Ektoparasiten auf gewissen Fischen (einige Cypriniden-Arten), und weiter werden die die grossen Eiersäcken tragenden Weibchen im Frühjahr und Frühsommer zahlreich beobachtet. Es scheint demnach höchst wahrscheinlich, dass das Verschwinden dieser Art aus dem Plankton hauptsächlich auf diesem Wechsel des Biotops beruht.

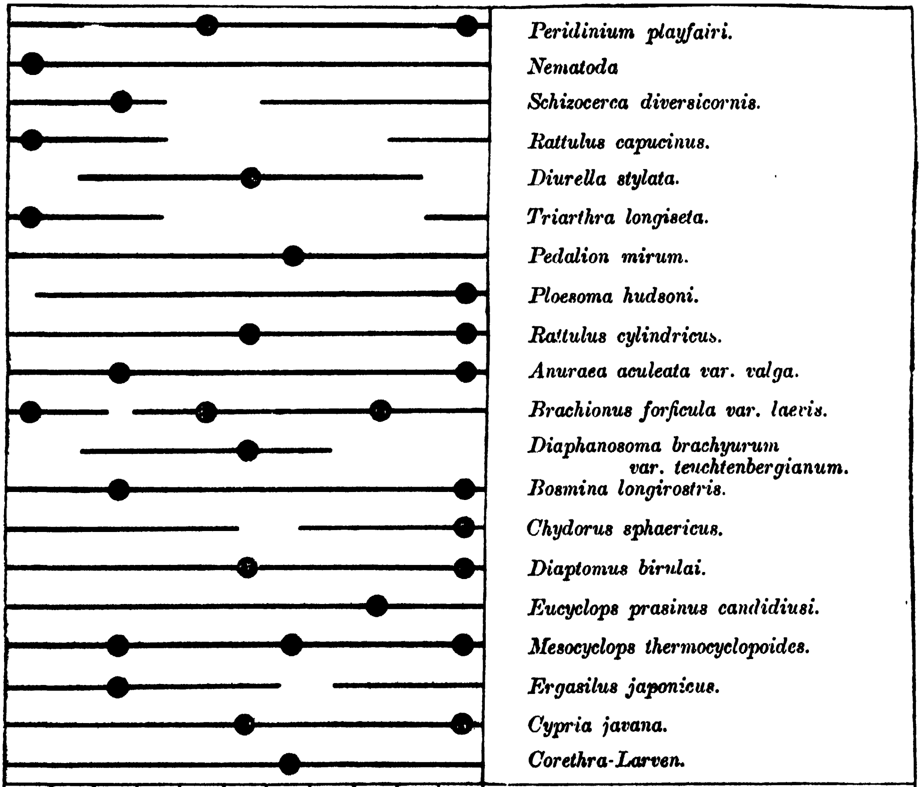
Die Schwankungen der Artenzahl im Laufe des Jahres sind aus dem Diagramm deutlich zu ersehen. Die maximale Entwickelung fällt bei der Mehrzahl der Arten in den Mai, wo sich nämlich 19 Arten, also 95% der Gesamtzahl, entwickeln.

Dem Mai zunächst steht der Januar mit 18 Arten, also mit 90% der Gesamtzahl. Für März, Juli und November ist die Anzahl der Arten gleich, nämlich 17, also 85% des Ganzen. Im August und

September erreicht die Artenzahl ihren Tiefstand, jedoch treten immerhin 16 Arten auf, also 80% der Gesamtzahl.

Was die Verteilung der Maxima auf die einzelnen Monate anbetrifft, so kommt zuerst der Januar in Betracht. Dieser Monat weist nämlich die höchste Anzahl der Maxima auf, indem 9 Arten, also 45% der Gesamtzahl, ihr Maximum erreichen.

Ordnet man die Monate nach der Häufigkeit der auftretenden Maxima, so stehen dem Januar zunächst der Mai und August mit je



17		19		17	16	16		17		18	Zahl der auftretenden Species.
4		5		2	5	3		2		9	Zahl der Maxima.
20.6		26.5		28.7	25.3	28.6		21.8		19.7	Wasser-Temperatur °C.
III 1929		V		VII	VIII	IX		XI		I 1930	Monate.

Fig. 4.

Dauer des Auftretens und Lage der Maxima des Zooplanktons nach Zeit und Temperatur im See Candidius (III, 1929—I, 1930).

● Lage des Maximums. ——— Dauer des Auftretens.

25%, der März mit 20%, der September mit 15%, und zuletzt der Juli und November mit je 10% der Gesamtarten in maximaler Entfaltung.

Bei dieser Gelegenheit wollen wir ferner noch die Periodizität des Auftretens der einzelnen Planktozoen erörtern.

Es besteht kein Zweifel, dass alle äusseren Milieu-Bedingungen für die Periodizität der Entwickelung der Planktonorganismen eine grosse Rolle spielen. Da aber während der vorliegenden Untersuchung keine kontinuierliche Arbeit über die Schwankungen des Chemismus des Seewassers unternommen wurde, so können wir vorerst die Periodizität nur in thermischer Hinsicht darstellen.

In der ersten Linie stehen solche Tiere, welche in ihrem Auftreten und der Ausbildung ihrer Maxima vom Jahresgang der Wassertemperatur völlig unabhängig zu sein scheinen und daher als extrem eurytherm zu bezeichnen sind. Folgende 8 Arten gehören zu dieser Gruppe:

Peridinium playfairi
Rattulus cylindricus
Anuraea aculeata var. *valga*
Brachionus forficula var. *laevis*
Bosmina longirostris
Diaptomus birulai
Mesocyclops thermocyclopoides
Cypria javana.

Die Mehrzahl dieser Arten bildete im Laufe des Beobachtungsjahres 2 Maxima aus, mit Ausnahme von *B. forficula* var. *laevis* und *M. thermocyclopoides,* bei welchen 3 Maxima sich merkbar machten.

Diese Arten setzen, im allgemeinen, ihre Entwickelung zwischen je zwei aufeinanderfolgenden Maxima fort, ohne dass ein völliges Zurückgehen zu stande kommt. Nur *B. forficula* var. *laevis* liess eine Unterbrechung im Mai erkennen, deren Ursache wir freilich nicht kennen.

Weiterhin gibt es eine Gruppe von Planktontieren, deren maximale Massenentfaltung in den Bereich einer ziemlich niederen Wassertemperatur, etwa von 19.7° bis 21.8°C fällt.

Diese Gruppe ist also als oligotherm zu bezeichnen und enthält sowohl perennierende, als auch nicht perennierende Arten.

Perennierende Arten:

Nematoda

Eucyclops prasinus candidiusi

Nichtperennierende Arten:

Rattulus capucinus

Triarthra longiseta

Ploesoma hudsoni

Chydorus sphaericus.

Zuletzt können wir solche Arten unterscheiden, deren maximale Massenentfaltung streng an eine höhere Wassertemperatur gebunden ist, welche daher als polytherm zu bezeichnen sind.

Die Ausbildung der Maxima fällt bei diesen Arten in den Temperaturbereich von 26.5° bis 28.7°C.

Folgende 6 teils perennierende, teils nicht perennierende Arten gehören zu dieser Gruppe:

Perennierende Arten:

Pedalion mirum

Corethra-Larven

Nichtperennierende Arten:

Diurella stylata

Schizocerca diversicornis

Diaphanosoma brachyurum var. *leuchtenbergianum*

Ergasilus japonicus.

B. SPEZIELLER TEIL.

Wie schon in dem vorhergehenden, allgemeinen Teil erwähnt, weisen die in unserem See vorkommenden Planktonorganismen während des Beobachtungsjahres eine je nach der Species verschiedene Periodizität des Auftretens auf.

In dem nachfolgenden speziellen Teil geben wir eine nähere Darstellung erstens der jährlichen Schwankung und zweitens der täglichen Schwankung der Vertikalverteilung der einzelnen Planktontiere.

Zugleich wird auch die Schwankung der Geschlechtsverhältnisse gewisser Arten, bei welchen die Geschlechter deutlich unterscheidbar sind, berücksichtigt.

1. Dinoflagellata.

Peridinium playfairi Lindemann 1931.

Diese Species ist eine extrem eurytherme Form; sie tritt nämlich in unserem See zu allen Jahreszeiten auf und gehört, wegen ihres sehr zahlreichen Vorkommens, zu den Leitformen.

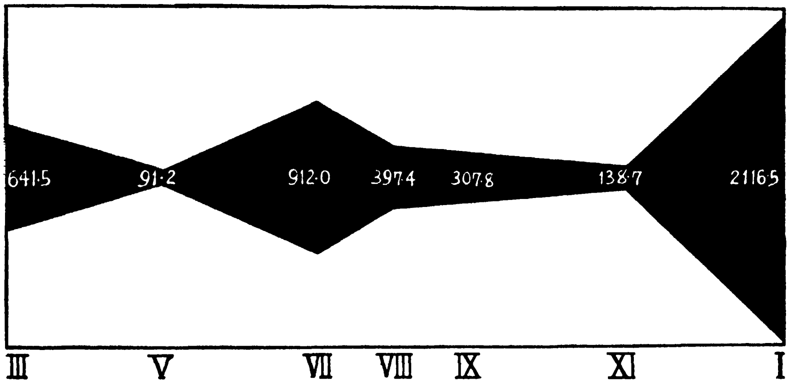


Fig. 5.
Periodizitätsdiagramm von *Peridinium playfairi* LINDEMANN im Laufe des Jahres (III, 1929—I, 1930).

Betrachtet man das Periodizitätsdiagramm, so ist zu ersehen, dass diese Art während des Beobachtungszeitraumes zwei Maxima, eines im Juli uud eines im Januar, und auch zwei Minima, eines im Mai und eines im November besitzt.

Die ziemlich hohe Bevölkerungsdichte im Frühling geht allmählich zurück, um im Mai das erste Minimum zu erreichen.

Etwa von diesem Zeitpunkt an nimmt die Individuenzahl plötzlich zu und erreicht das erste Maximum im Juli. Darauf folgt wieder ein allmähliches Zurückgehen gegen den Spätherbst, wo das zweite Minimum erreicht wird. Die nunmehr einsetzende Entfaltung des *P. playfairi* ist ausserordentlich lebhaft, und die Individuenzahl steigt in der Periode der zweiten maximalen Massenentfaltung, die im Spätwinter stattfindet, auf durchschnittlich 2116.5 pro 1 L. Die aktuelle Individuenzahl aber betrug in einer Probe 2410 pro 1 L. im Januar 1930.

Das Auftreten von *P. playfairi* scheint demnach von thermischen Beziehungen ganz unabhängig zu sein, da die beiden maximalen Massenentfaltungen in zwei thermisch vollkommen entgegengesetzte Jahreszeiten fallen. Ruttner gibt etwa die gleiche Darstellung für *P. willei* bei der Untersuchung der Lunzer Seen, doch besteht der Unterschied, dass unsere Species zu allen Jahreszeiten als Leitform zu bezeichnen ist.

Was die Vertikalverteilung von *P. playfairi* anbetrifft, so ist nichts besonderes festzustellen.

2. **Nematoda** (unbestimmte Species).

Das Auftreten eines freilebenden Nematoden im freien Wasser unseres Sees ist regelmässig, doch ist seine Häufigkeit das ganze Jahr hindurch äusserst gering.

Ursprünglich gehören die freilebenden Nematoden zweifelsohne zur Bodenfauna; sie kommen jedoch in unserem See sowohl in der tiefsten, als auch in der oberflächlichen Wasserschichte als Plankter vor.

Wie schon aus rein biologischen Gründen zu schliessen, wird ihr Vorkommen in der tiefsten Wasserschichte am häufigsten sein, ein Schluss, der durch die tatsächliche Beobachtung vollauf bestätigt wird.

Was die jährliche Schwankung des Auftretens der freilebenden Nematoden betrifft, so wäre natürlich eine nähere Untersuchung des Bodenschlammes erforderlich; da wir keine solche Untersuchung vorgenommen haben, können wir vorerst nur die Periodizität nach der Häufigkeit ihres Auftretens in der freien Wasserschichte, und auch diese nur mehr oder weniger vermutungsweise beurteilen.

Wegen des äusserst spärlichen Auftretens ist keine tabellarische Darstellung möglich, doch scheint die maximale Massenentfaltung etwa im Beginn des Frühlings stattzufinden und darauf ein allmähliches Zurückgehen gegen den Winter zu folgen.

3. Rotatoria.

Schizocerca diversicornis DADAY 1855.

Schizocerca diversicornis ist sehr interessant in ihrem Auftreten. Ihr lebhaftes Auftreten scheint in unserem See auf drei oder vier Monate (März-Juli) beschränkt zu sein.

Die maximale Massenentfaltung wird nach einer etwa im März einsetzenden plötzlichen Entwickelung schon im Frühsommer erreicht. In gleicher Weise ist auch das Zurückgehen ganz plötzlich, da schon in den Juli-Proben *Sch. diversicornis* nicht mehr zu finden ist. In den folgenden Monaten, nämlich vom August bis Januar des folgenden Jahres, ist die Bevölkerungsdichte äusserst gering.

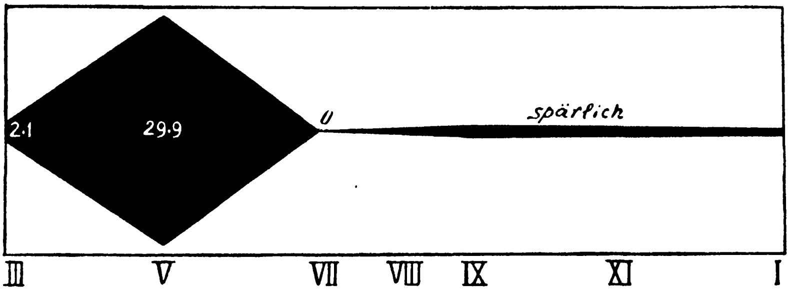


Fig. 6.
Periodizitätsdiagramm von *Schizocerca diversicornis* DADAY im Laufe des Jahres (III, 1929—I, 1930).

Sch. diversicornis gehört also ohne Zweifel zu den monozyklischen Typen. Jedoch äussert sich in der Lage des Maximums ein Unterschied von den anderen monozyklischen Typen, indem nur bei dieser Art das Maximum mit dem Aufstieg der Temperatur im Spätfrühling in inniger Beziehung steht.

Für die Betrachtung der täglichen Schwankung von *Sch. diversicornis* führen wir als Beispiel die Beobachtung im Mai an, wo die maximale Massenentfaltung dieser Art vor sich geht.

Unsere Beobachtung beginnt am Frühmorgen, 5 h. Es ist daher noch dämmerig; die maximale Volksdichte findet sich hier in der mittleren, das Minimum in der tiefsten Wasserschichte.

Mit dem direkten Sonnenschein des Morgens auf der Seeoberfläche erfolgt ein temporärer Abfall an der Oberfläche und im Gegenteil eine ziemliche Zunahme in der tiefsten Wasserschichte; dabei bleibt aber die maximale Volksdichte in der mittleren Wasserschichte bestehen. Diese Vertikalverteilung dauert ohne besondere Veränderung bis 9 h.

Eine auffallende Veränderung tritt aber gegen Mittag ein. Zu dieser Zeit entsteht nämlich eine erstaunliche Ansammlung von Individuen in der mittleren Wasserschichte und ein wiederholtes Zurückgehen in der Tiefe. Man kann dieses Stadium als eine Stufe der Aufwärtsbewegung dieser Species betrachten, wenn man die in der Folge entstehenden Verteilungsverhältnisse berücksichtigt.

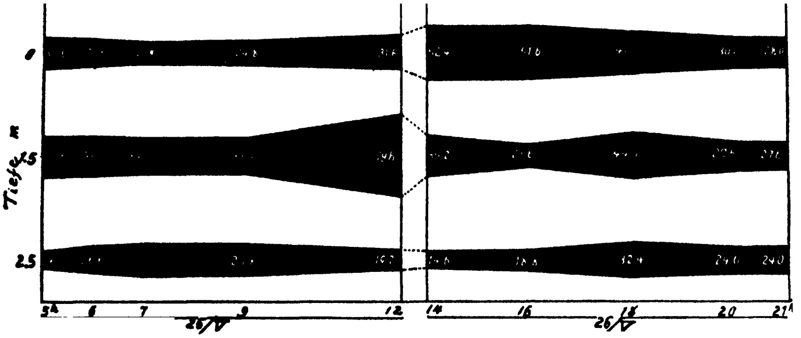


Fig. 7.

Vertikalverteilung von *Schizocerca diversicornis* DADAY im Laufe des Tages (25-26 Mai, 1929). Sonnenaufgang: 5.11 h. Sonnenuntergang 18.38 h.

Wenn auch zwischen den beiden Beobachtungen ein Zwischenraum von 26 Stunden liegt, sollen zunächst die Verteilungsverhältnisse unter denselben meteorologischen Bedingungen erklärt werden.

Betrachtet man die Verteilungsverhältnisse um 14 h, so fällt es auf, dass hier die maximale Massenentfaltung an der Oberfläche und dementsprechend ein merkwürdiges Zurückgehen in der mittleren Wasserschichte zu beobachten ist.

Etwa die gleichen Verteilungsverhältnisse findet man auch um 16 h. Es zeigt sich nämlich auch hier die maximale Volksdichte an der Oberfläche, und ein weiteres Zurückgehen in der mittleren Wasserschichte.

Diese Verteilungsverhältnisse sind als die maximale Periode der Aufwärtsbewegung zu bezeichnen, weil in der darauffolgenden Periode (18 h) eine entschiedene Änderung in der Vertikalverteilung einsetzt. Zu dieser Stunde ist die Sonne schon hinter einem dem See vorgelagerten Hügel verschwunden, und die Abenddämmerung beginnt.

In dieser Periode entsteht ein merklicher Abfall in der Oberflächenschicht und dementsprechend eine Zunahme in der mittleren und der tiefsten Wasserschichte; die maximale Volksdichte findet sich in der mittleren Schichte. Dieses Verteilungsverhältnis bezeichnet also eine Abwärtsbewegung der Tiere.

Diese Abwärtsbewegung setzt sich gleichmässig fort, bis zuletzt eine Ausgleichung der Bevölkerungsdichte in allen Wasserschichten erreicht ist; etwa um 20 h oder 21 h ist dieser Ausgleich zum grössten Teil vollendet.

Betrachtet man die ganze Serie der Vertikalverteilung im Laufe des Tages, so wird es deutlich, dass *Sch. diversicornis* während der Beobachtungszeit eine zweimalige Abwärtsbewegung ausführt, eine am Morgen (etwa zwischen 6 h und 9 h) und eine am Abend; dazwischen ist eine Aufwärtsbewegung eingeschoben, welche gegen Mittag beginnt und gegen 16 h ihr Maximum erreicht.

Zur Zeit ist es uns unmöglich, die Verteilungsverhältnisse während der Mitternachtstunden festzustellen, da wir leider während dieser Stunden keine Proben entnommen haben.

Rattulus capucinus (WIERZ. u. ZACHAR.) 1893.

Rattulus capucinus gehört in unserem See nicht zu den Leitformen. Sein Auftreten ist von ausgeprägt monozyklischem Typus und fällt in den niederen Temperaturgang der Frühlingsmonate; er ist also als eine kalt-stenotherme Form zu bezeichnen.

Betrachtet man das Periodizitätsdiagramm, so fällt es auf, dass die maximale Massenentfaltung unserer Species in den März fällt, dass aber dabei die Individuenzahl sehr gering (1.9 pro 1 L.) ist.

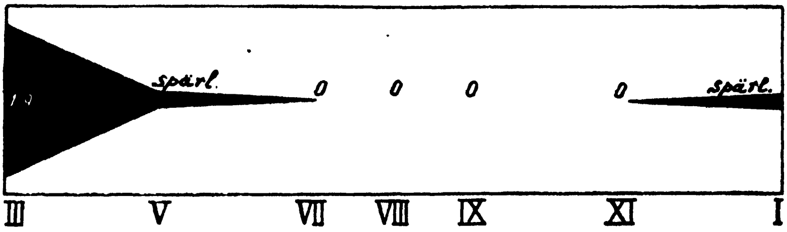


Fig. 8.

Periodizitätsdiagramm von *Rattulus capucinus* (WIERZ. u. ZACHAR.) im Laufe des Jahres (III, 1929—I, 1930).

Mit dem steigenden Temperaturgang des Frühlings scheint nun ein plötzliches Zurückgehen dieser Species stattzufinden, da sie schon im Mai nur noch spärlich zu finden ist.

In den Monaten zwischen Juli und November verschwindet dieses Rotatorium vollständig aus dem Plankton, wie das Periodizitätsdiagramm zeigt.

Die Periode des Wiedererscheinens von *R. capucinus* scheint in unserem See ungefähr zwischen November und Januar des folgenden Jahres zu liegen, da in den Proben des letzteren Monats schon ein spärliches Auftreten bemerklich ist.

Was die Vertikalverteilung dieser Species anbetrifft, so ist nichts besonderes festzustellen.

Diurella stylata EYFERTH 1878.

Das Auftreten dieser Art fällt, im Vergleich mit dem von *R. capucinus*, in die gerade entgegengesetzte Jahreszeit, indem es nämlich von der hohen Temperatur des Sommers abhängt.

D. stylata ist also als eine warm-stenotherme Form zu bezeichnen. Allerdings gehört diese Species selbst in der Periode des Maximums nicht zu den Leitformen unseres Sees.

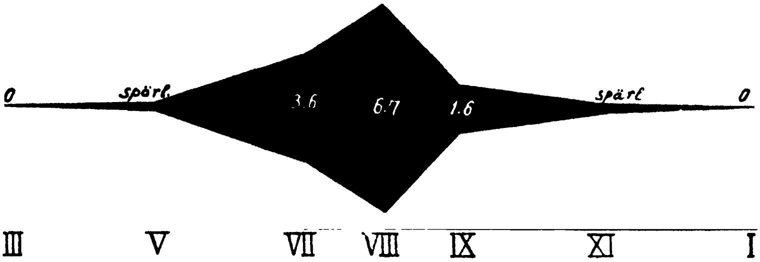


Fig. 9.
Periodizitätsdiagramm von *Diurella stylata* EYFERTH 1878 im Laufe des Jahres (III, 1929- I, 1930).

Die Probeentnahmen im Frühjahre zeigen keine Spur des Auftretens von *D. stylata.* Die lebhafte Entwickelung scheint etwa im Frühsommer zu beginnen, weil die Bevölkerungsdichte im Spätfrühling noch ziemlich gering ist.

Die maximale Massenentfaltung wird sodann im Hochsommer erreicht, wo die Individuenzahl durchschnittlich 6.7 pro 1 L. beträgt.

Doch muss ich bei dieser Gelegenheit darauf aufmerksam machen, dass die Proben, welche den hier eingezeichneten Werten der Bevölkerungsdichte zu Grunde liegen, unmittelbar vor der Ankunft eines Taifuns entnommen wurden, und dass offenbar der plötzliche, durch den heftigen Sturm bedingte Abfall der Wassertemperatur gerade auf *D. stylata* besonders schädlich einwirkte und damit ein plötzliches Zurückgehen der Individuenzahl verursachte.

Die schädigende Wirkung des Sturmes war so intensiv, dass wir kurz nach dem Sturme die sehr spärliche Bevölkerungsdichte von 0.7–0.8 pro 1 L. berechnet haben. Auf die schädigende Wirkung dieses Sturmes werden wir später nochmals zurückkommen.

Ein Wiedererwachen der Entwickelung tritt dann mit der Wiederkehr der höheren Temperatur ein, doch scheint dasselbe nicht sehr ausgiebig zu sein, da im September, trotz der immer noch hohen Temperatur, die Bevölkerungsdichte nur 1.6 pro 1 L. beträgt.

Von dieser Jahreszeit an geht die Individuenzahl allmählich zurück, um im Spätherbst eine sehr geringe Bevölkerungsdichte zu erreichen und zuletzt im Winter in das Ruhestadium überzugehen.

Obgleich streng genommen das Periodizitätsdiagramm in Wirklichkeit zweigipfelig ist, ist das Absinken der Individuenzahl zwischen den beiden Gipfeln zweifelsohne eine Ausnahmeerscheinung, verursacht durch die schädigende Wirkung des Sturmes, und demnach ist das Auftreten von *D. stylata* als zum monozyklischen Typus gehörig zu bezeichnen.

Triarthra longiseta Ehrenberg 1838.

Diese Art gehört einwandfrei zu den kalt-stenothermen Formen, da ihr Auftreten in unserem See mit dem niederen Temperaturgang des Frühjahrs im Zusammenhang steht.

Das Periodizitätsdiagramm dieser Art stimmt also im grossen und ganzen mit dem von *Rattulus capucinus* überein, wenn es auch insofern einen Unterschied zeigt, als die vorliegende Species in ihrer maximalen Massenentfaltung eine hohe Bevölkerungsdichte besitzt und demnach wenigstens in dieser Periode als Leitform zu bezeichnen ist.

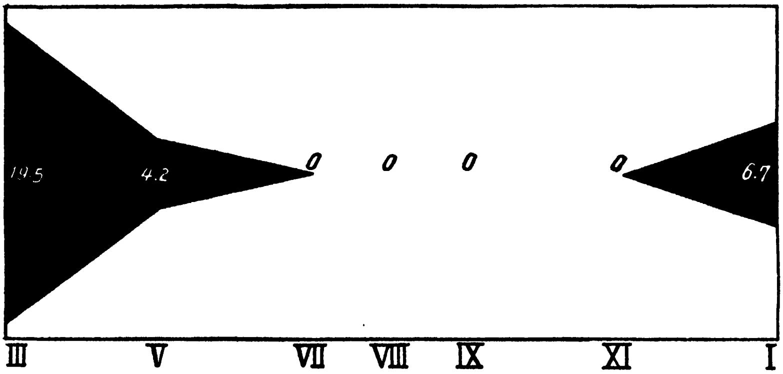


Fig. 10.
Periodizitätsdiagramm von *Triarthra longiseta* EHRENBERG im Laufe des Jahres (III, 1929–I, 1930).

Die maximale Massenentfaltung dieser Species fällt wie bei *R. capucinus* in den März, doch ist die Bevölkerungsdichte bedeutend höher und beträgt durchschnittlich 19.5 pro 1 L.

Zusammenhängend mit dem Temperaturanstieg im Frühling findet ein ziemlich plötzliches Zurückgehen der Individuenzahl statt; im März sinkt die Anzahl auf den vergleichsweise niedrigen Wert von durchschnittlich 4.2 pro 1 L., und im Juli verschwindet die Art völlig aus den Proben.

Nach einer verlängerten Pause in der Entwickelung, etwa vom Frühsommer bis zum Spätherbst, beginnt das Wiedererwachen der Entfaltung von *T. longiseta* im Frühwinter, und schon im Januar des folgenden Jahres wird eine ziemlich auffällige Massenentfaltung erkennbar.

Wenn man hier das Verhältnis der Bevölkerungsdichte zwischen März (1929) und Januar (1930) in Betracht zieht, so lässt sich sogleich sagen, dass *T. longiseta* in auffallend plötzlicher Weise ihr Maximum erreicht, und weiter, dass sie in unserem See sicher zu dem monozyklischen Typus gehört.

Was die Vertikalverteilung dieser Art im Laufe des Tages anbelangt, so wollen wir zunächst an Hand der Serie von Schöpffängen, welche an den Tagen 25. und 26. Januar 1930 gemacht wurden, eine Erklärung geben.

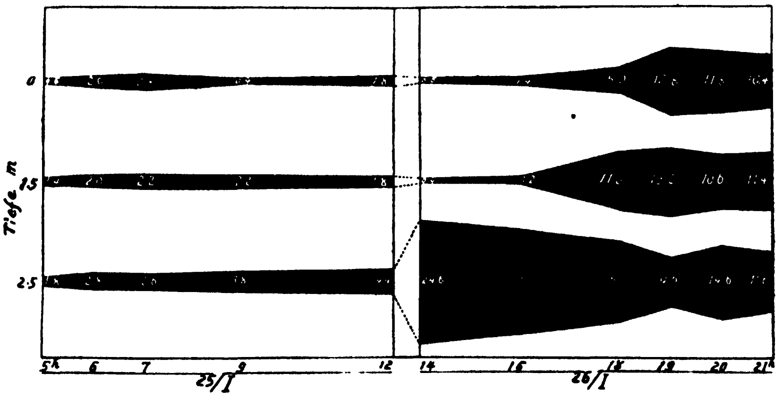


Fig. 11.
Vertikalverteilung von *Triarthra longiseta* EHRBG. im Laufe des Tages (25, 26 Januar, 1930) Sonnenaufgang: 6.41 h, Sonnenuntergang; 17.38 h.

Die Bevölkerungsdichte am Frühmorgen ist in allen Wasserschichten von 0 m bis zu 2.5 m ziemlich gering; es besteht also eine Ausgleichung der Vertikalverteilung.

Darauf folgt eine schwache Entfaltung in der tiefsten Wasserschichte gegen Mittag, ohne aber von einem auffälligen Zurückgehen in der oberen Wasserschichte begleitet zu sein.

Eine starke Veränderung tritt dagegen mit dem Beginn des Nachmittags ein, indem eine plötzliche Massenentfaltung, vorerst nur in der tiefsten Wasserschichte, einsetzt, wie dies die Verteilungsverhältnisse um 14 h und 16 h deutlich erweisen. Dabei bleibt die Bevölkerungsdichte in der Wasserschichte von 0–1.5 m im wesentlichen unverändert.

Dieses Verteilungsverhältnis ist als der Beginn der Aufwärtsbewegung von *T. longiseta* zu bezeichnen, wie eine Betrachtung der am Abend herrschenden Verhältnisse unzweideutig ergibt.

Um 18 h, also eine halbe Stunde nach Sonnenuntergang, da an diesem Datum die Sonne um 17.38 h untergeht, zeigt sich nämlich eine plötzliche Massenentfaltung sowohl in der mittleren, als auch in der oberflächlichen Wasserschichte.

Die Aufwärtsbewegung wird im Laufe der Nacht weiter fortgesetzt, und um 19 h wird die maximale Massenentfaltung an der Oberfläche und eine ziemliche Abnahme in der tiefsten Wasserschichte beobachtet.

Von diesem Zeitpunkt an scheint die Aufwärtsbewegung nicht weiter fortzuschreiten, vielmehr wird eine schwache Abwärtsbewegung erkennbar, und zuletzt kommt eine Ausgleichung der Vertikalverteilung zustande.

Was die täglichen Schwankungen der Vertikalverteilung von *T. longiseta* anbetrifft, so können wir, soweit es die Untersuchungen im Januar erlauben, folgendes feststellen: *T. longiseta* repräsentiert in unserem See wesentlich einen Tiefenbewohner; ihre beträchtlichste Volksdichte besteht am hellen Tage, besonders vom Frühmorgen bis zum Mittag, in der tiefsten Wasserschichte, unmittelbar über dem Seegrunde. Die Aufwärtsbewegung ist schon am Beginn des Nachmittags erkennbar, nimmt aber nach Sonnenuntergang stark zu.

Auf die Frage, in welcher Weise dann die Wiederkehr der Verteilungsverhältnisse am Morgen zu stande kommt, haben wir leider vorläufig keine Antwort, in Ermangelung von Proben aus den Stunden um Mitternacht.

Pedalion mirum HUDSON 1871.

Obgleich diese Species in den Proben aller Beobachtungsmonate vertreten ist, ist ihre sehr beträchtliche Massenentfaltung von der hohen Wassertemperatur der Sommermonate abhängig; dementsprechend ist ihr Auftreten im Frühjahre auffallend spärlich.

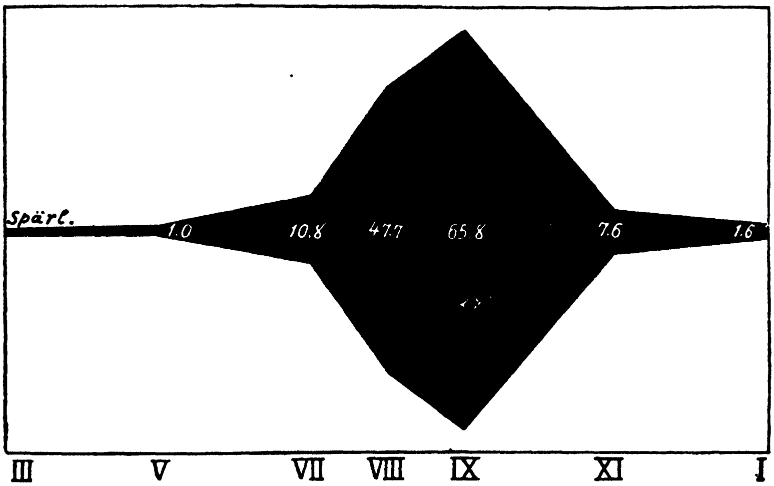


Fig. 12.
Periodizitätsdiagramm von *Pedalion mirum* HUDSON im Laufe des Jahres (III, 1929–I, 1930).

Betrachtet man das Periodizitätsdiagramm, so fällt es auf, dass das Auftreten dieser Art vom Frühjahr bis zum Frühsommer verhältnismässig spärlich ist, wenn auch ein allmählicher Anstieg schwach erkennbar ist.

Eine scharf ausgeprägte Massenentfaltung beginnt etwa im Hochsommer, um zuletzt im September das Maximum zu erreichen, wo die durchschnittliche Individuenzahl auf 65.8 pro 1 L., die aktuelle sogar auf 173.4 pro 1 L. ansteigt.

P. mirum **ist also während der Jahresmonate mit hoher Temperatur offenbar eine Leitform.**

Von dieser Jahreßeit an zeigt sich ein plötzliches Zurückgehen der Individuenzahl in Uebereinstimmung mit dem absteigenden Temperaturgang. Dieser Rückgang ist so plötzlich, dass wir schon im Spätherbst

eine Individuenzahl von nur 7.6 pro 1 L., und weiter im Januar des folgenden Jahres sogar eine solche von nur 1.6 pro 1 L. erreichen.

P. mirum ist demnach als eine warm-stenotherme Form zu bezeichnen, zwar fällt seine maximale Massenentfaltung in die spätere Periode der hohen Wassertemperatur.

Für die maximale Massenentfaltung dieser Species scheint demnach eine vorhergehende, und längere Zeit andauernde Periode hoher Wassertemperatur erforderlich zu sein.

Bei dieser Gelegenheit müssen wir wieder an die schädigende Einwirkung erinnern, welche der Sturm im August auf diese Species ausübte. Die plötzliche Veränderung der Milieu-Bedingungen, namentlich der plötzliche Abfall der Temperatur, bewirkte ein sofortiges starkes Zurückgehen dieser Species.

Das Diagramm ist auf die monatlichen Durchschnittswerte basiert, kann somit den vorübergehenden starken Rückgang der Individuenzahl zwischen August und September nicht zeigen. Tatsächlich beruht die maximale Massenentfaltung im September auf dem Wiedererwachen der Entfaltung infolge der Wiederkehr der für diesen Monat normalen hohen Temperatur. Dieser Rückgang ist ohne allen Zweifel als Ausnahmeerscheinung zu betrachten, und *P. mirum* gehört demnach zu dem monozyklischen Typus.

Ploesoma hudsoni (IMHOF) 1891.

Ploesoma hudsoni ist in unserem See von so spärlichem Auftreten, dass wir die Bevölkerungsdichte dieser Species diagrammatisch nicht darstellen können.

Ihre Massenentfaltung beginnt etwa zu Ende November, und im Januar wird die maximale Bevölkerungsdichte erreicht. Die Individuenzahl ist jedoch auch in diesem letzteren Monate sehr niedrig, und beträgt nur 0.2 pro 1 L.

Demnach gehört *P. hudsoni* nicht zu den Leitformen; nach ihrem Auftreten gehört die Art zu dem monozyklischen Typus.

Was die Vertikalverteilung dieser Species anbelangt, so fällt die grösste Dichte, soweit die Untersuchungsresultate im Januar beurteilen lassen, in die Wasserschichte von weniger als 1.5 m Tiefe.

Rattulus cylindricus (Imhof) 1891.

Rattulus cylindricus fehlt während unserer Beobachtung zu keiner Jahreszeit vollständig im Plankton. Dieses Rotatorium ist also in unserem See eine eurytherme Form.

Betrachtet man das Periodizitätsdiagramm des Auftretens, so fällt es auf, dass diese Art in ihrem jährlichen Lebensgang zwei Maxima besitzt, eines im August und eines im Januar.

Die Kurve der Bevölkerungsdichte zeigt im Frühling absteigende Tendenz, und erreicht im Mai das erste Minimum.

Etwa von dieser Jahreszeit an beginnt eine allmähliche Entfaltung, und die erste maximale Massenentfaltung fällt in den Hochsommer, mit einer durchschnittlichen Individuenzahl von 12.9 pro 1 L.

Auf die plötzliche Veränderung der Milieubedingungen durch den im August herrschenden Sturm folgte ebenfalls ein starkes Zurückgehen der Individuenzahl dieser Species.

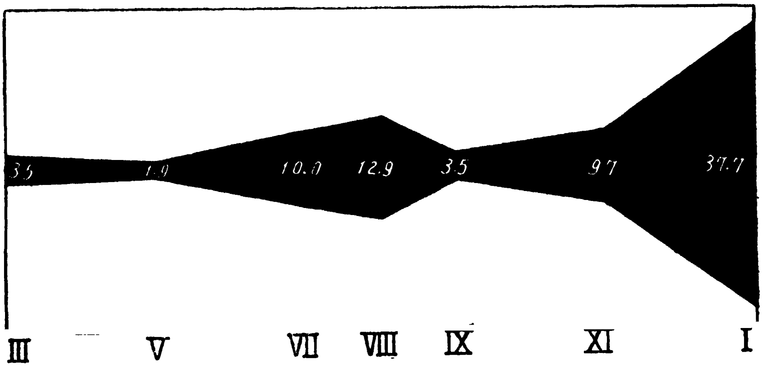


Fig. 13.

Periodizitätsdiagramm von *Rattulus cylindricus* (IMHOF) im Laufe des Jahres (III, 1929—I, 1930).

Das Wiedererwachen der Entwickelung infolge der Wiederkehr der hohen Wassertemperatur scheint aber nicht von grossem Belang zu sein, da die Bevölkerungsdichte auch im September stark zurückgeht.

Von dieser Periode an geht nunmehr die Individuenzahl nicht weiter zurück, sondern steigt allmählich gegen den Spätherbst.

Die zweite Periode der Hauptproduktion beginnt aber erst im Frühwinter, und der zweite, sehr ausgeprägte Höhepunkt der Entfaltung wird erst im Januar des folgenden Jahres erreicht, wo die Individuenzahl durchschnittlich 37.7 pro 1 L. beträgt.

Das Periodizitätsdiagramm von *R. cylindricus* kann also zu keiner Zeit mit dem Temperaturgang des Jahres in Zusammenhang gebracht werden, da die beiden maximalen Massenentfaltungen in thermisch völlig entgegengesetzte Jahreszeiten fallen.

Zusammenfassend kann gesagt werden, dass *R. cylindricus* ein Plankter von dizyklischem Auftreten und weiter von ausgeprägt eurythermem Verhalten ist.

Was die Vertikalverteilung von *R. cylindricus* betrifft, so zeigt diese Species in unserem See mannigfaltige Veränderungen, welche aber niemals mit dem täglichen Gang der Lichtintensität in irgend einem Zusammenhang zu stehen scheinen.

Anuraea aculeata var. *valga* (EHRENBERG) 1838.

Dieses Rotatorium gehört zu den eurythermen Formen, doch ist sein Auftreten auch während der Sommermonate sehr spärlich. Selbst in der Periode ihrer maximalen Massenentfaltung kann diese Species nicht zu den Leitformen gezählt werden.

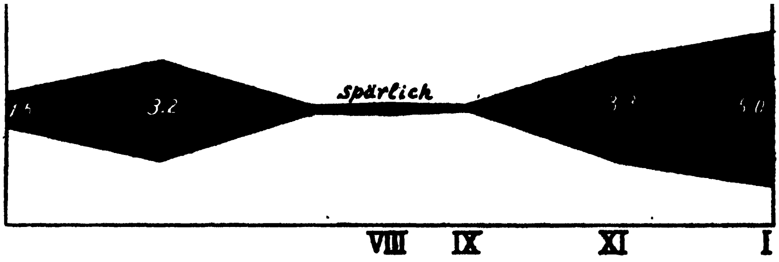


Fig. 14.

Periodizitätsdiagramm von *Anuraea aculeata* var. *valga* (EHRBG.) im Laufe des Jahres (III, 1929—I, 1930).

Das Periodizitätsdiagramm von *A. a.* var. *valga* weist im Rahmen des Beobachtungsjahres eine zweigipfelige Kurve auf.

Ein allmählicher Anstieg der Bevölkerungsdichte ist im Frühling erkennbar, und das erste Maximum wird im Spätfrühling beobachtet. Etwa von dieser Zeit ab zeigt dieses Rotatorium eine allmähliche Abnahme der Individuenzahl, im Zusammenhang mit der aufsteigenden Temperatur des Sommers, und fällt schon im Juli auf das Minimum. Die Bevölkerungsdichte in dieser Periode ist auffallend gering.

Diese minimale Bevölkerungsdichte bleibt etwa bis Ende September ununterbrochen bestehen. Es ist anzunehmen, dass der starke Rückgang der Individuenzahl durch die hohe Temperatur des Sommers verursacht wird, da der Temperaturgang während der Monate Juli-September in unserem See stark ansteigt.

Nach der etwa dreimonatigen Dauer des Ruhestadiums beginnt ein Wiedererwachen der Entfaltung etwa in der Mitte des Herbstes, und im Zusammenhang mit dem allmählich sinkenden Temperaturgang des Seewassers gegen den Winter hin erfolgt eine allmähliche Zunahme, um im folgenden Januar das zweite Maximum zu erreichen.

A. a. var. *valga* weist also in der Periodizität ihres Auftretens zwei Maxima auf, eines im Mai, das andere im Januar.

Dabei ergibt sich ein merkwürdiger Widerspruch in ihrem Verhalten gegenüber dem Temperaturgang im Winter und dem im Frühling.

Der sehr ausgeprägte Rückgang während der Sommermonate und die nachfolgende auffällige maximale Massenentfaltung im Januar scheinen auf den ersten Blick genügend Gründe darzubieten, die Art als kaltstenotherm zu bezeichnen. Während dieser Periode geht die Vermehrung mit dem Abstieg der Temperatur des Seewassers einher.

Anders ist es im Frühling. Hier folgt auf den beachtenswerten Rückgang im März eine maximale Massenentfaltung im Mai, die Vermehrung steht also zu dieser Zeit mit dem Anstieg der Wassertemperatur in Beziehung.

In Würdigung dieses widersprechenden Verhaltens, sowie des Umstandes, dass die Art zu keiner Jahreszeit im Plankton gänzlich fehlt, muss sie als eurytherme Form bezeichnet werden, wenn auch ihre höchste Massenentfaltung mit dem niederen Temperaturgang des Seewassers verknüpft ist.

Dem Auftreten nach gehört sie, wie *Rattulus cylindricus*, zum dizyklischen Typus.

In Bezug auf die Vertikalverteilung dieser Species lässt sich nichts bestimmtes aussagen, obgleich sie im Laufe des Tages, ähnlich wie *R. cylindricus*, mannigfaltige Bilder der Verteilung darbietet.

Brachionus forficula var. *laevis* Apstein 1907.

B. forficula var. *laevis* ist ein interessantes Rotatorium, das in unserem See durch ein kompliziertes Periodizitätsdiagramm gekennzeichnet ist. Für dieses Rädertier verzeichnen wir während des Beobachtungsjahres drei Maxima (im März, Juli und November) und auch drei Minima (im Mai, August-September und Januar). Es gehört also zu den polyzyklischen Formen. Doch ist *B. forficula* var. *laevis* keine Leitform in unserem See; die Individuenzahl beträgt selbst während der maximalen Massenentfaltung im Juli nur 4.7 pro 1 L.

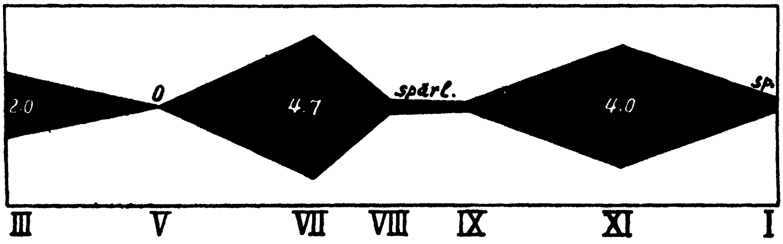


Fig. 15.
Periodizitätsdiagramm von *Brachionus forficula* var. *laevis* APSTEIN im Laufe des Jahres (III, 1929—I, 1930).

Die erste maximale Massenentfaltung geht im März vor sich, ist aber im Vergleich mit den beiden anderen, welche in den Juli und November fallen, nicht sehr bedeutend.

Darauf folgt ein Zurückgehen, und im Mai wird das erste Minimum erreicht. In diesem Monat verschwindet das Tier völlig aus dem Plankton.

Etwa von dieser Zeit an scheint wieder eine lebhafte Entwickelung dieser Species stattzufinden, da das zweite Maximum schon im Juli herbeigeführt wird.

Darauf folgt wieder ein sehr plötzliches Zurückgehen und es erfolgt das zweite Minimum im August. Die Bevölkerungsdichte in dieser Periode ist äusserst gering. Dieses spärliche Auftreten dauert sicher bis Ende September.

Etwa von diesem Zeitpunkt an setzt wieder eine Phase kräftiger Entwickelung ein, um gegen das Ende des Herbstes das dritte Maximum zu erreichen. In letzterer Periode ist die Bevölkerungsdichte etwa gleich jener im zweiten Maximum.

Das darauffolgende Zurückgehen ist nicht plötzlich, und die Species ist noch im Januar des folgenden Jahres vertreten, wenn auch spärlich.

Wie aus dem oben dargestellten Periodizitätsdiagramm ohne weiteres zu ersehen, lässt sich die Periodizität von *B. forficula* var. *laevis* in unserem See auf keine Weise mit dem Jahresgang der Temperatur in Zusammenhang bringen, und es scheint also der Temperaturfaktor für die Periodizität des Auftretens dieser Species direkt keine besondere Rolle zu spielen.

Die maximale Massenentfaltung der Rotatorien kann, im allgemeinen, als Anzeiger der Sexual-Periode gelten, und die Tatsache, dass die Maxima regelmässig in jeden vierten Monat fallen und nicht von dem Temperaturgang abhängen, lenkt unsere Aufmerksamkeit auf die Vermutung PUNNETT's (1906), dass für die Entstehung der Periodizität der Rotatorien innere Ursachen die Hauptrolle spielen.

Was die Vertikalverteilung von *B. forficula* var. *laevis* anbelangt, so ist eine Periodizität im Laufe des Tages schwach erkennbar.

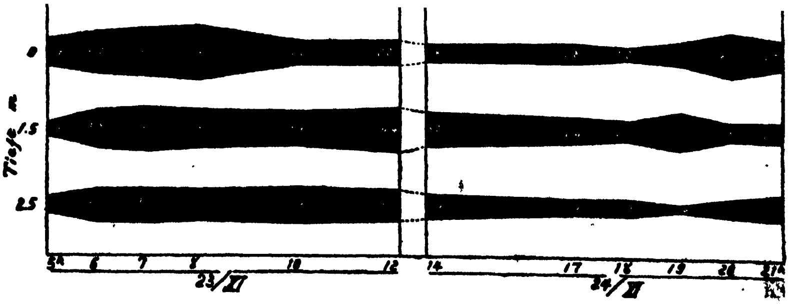


Fig. 16.

Vertikalverteilung von *Brachionus forficula* var. *laevis* APSTEIN im Laufe des Tages (23-24 XI, 1929). Sonnenaufgang: 6.16 h, Sonnenuntergang: 17.10 h.

In den früheren Tageszeiten zeigt *B. forficula* var. *laevis* die stärkste Entfaltung an der Oberfläche, oder besser gesagt, vom Frühmorgen bis etwa 8 h, findet eine stetige Aufwärtsbewegung der Species statt.

Darauf folgt mit der zunehmenden Intensität des Sonnenscheins eine plötzliche Abnahme in der mittleren Wasserschichte, wie das Verteilungsverhältnis um 10 h zeigt. Letzteres Verhältnis bleibt ohne wesentliche Veränderung etwa bis Sonnenuntergang erhalten.

Nach Sonnenuntergang aber zeigt sich in der mittleren Wasserschichte eine Veränderung, bestehend in einer plötzlichen Zunahme der Individuenzahl, wie sich aus der Verteilung um 19 h ergibt. Dieses Verhältnis ist, m. A. n., als eine Vorstufe der Aufwärtsbewegung des Tieres zu bezeichnen, welche in der nächsten Stunde (20 h) eine beträchtliche Massenentfaltung in der oberflächlichen Wasserschichte herbeiführt.

Zusammenfassend zeigt *B. forficula* var. *laevis* täglich zwei Aufwärtsbewegungen, eine am Frühmorgen, die andere am Abend; und eine Abwärtsbewegung während der Tageshelle, letztere nicht ganz so deutlich erkennbar.

Cladocera.

Bosmina longirostris (MÜLLER) 1785.

Bosmina longirostris ist eine Hauptkomponente des Zooplanktons, d. h. eine Leitform, in unserem See. Dieses Krebschen fehlt während unserer Beobachtung zu keiner Jahreszeit im Plankton, ist also als eine eurytherme Form zu bezeichnen.

Eine Betrachtung des Periodizitätsdiagramms ergibt, dass, von der ziemlich geringen Bevölkerungsdichte im März ausgehend, eine plötzliche ungeheure Massenentfaltung im Mai in Erscheinung tritt. Die Individuenzahl in dieser Periode erreicht ausserordentliche Werte, durchschnittlich 249.2 pro 1 L.

Darauf folgt dann ein Zurückgehen der Individuenzahl, im Zusammenhang mit dem allmählich aufsteigenden Temperaturgang gegen Sommer.

Das Zurückgehen geschieht so plötzlich, dass schon im Juli eine Individuenzahl von durchschnittlich nur noch 8.8 pro 1 L. erreicht wird.

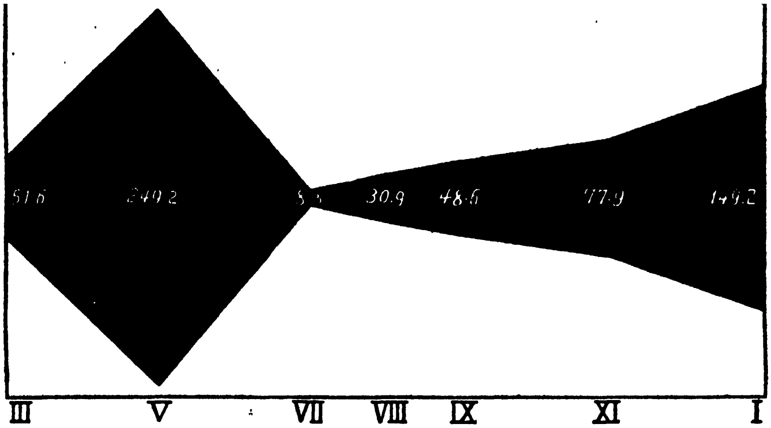


Fig. 17.
Periodizitätsdiagramm von *Bosmina longirostris* (MUELLER) im Laufe des Jahres (III, 1929—I, 1930).

Nach dieser Periode des starken Zurückgehens beginnt ein Wiedererwachen der Entfaltung im Laufe des Jahres, doch ist die Zunahme bis zum Beginn des Herbstes nicht sehr auffallend.

Erst im Spätherbst erfolgt eine mehr ausgeprägte Vermehrung und wird das zweite maximale Massenentfaltung im Januar des folgenden Jahres erreicht. Hier beträgt die Individuenzahl durchschnittlich 149.2 pro 1 L.

Das Periodizitätsdiagramm zeigt deutlich, dass *B. longirostris* in unserem See in ihrem jährlichen Lebensgang zwei Maxima besitzt, eines im Mai, das andere im Januar, und auch zwei Minima, eines im März, das zweite im Juli. Es ergibt sich also eine Übereinstimmung von *B. longirostris* mit *Anuraea aculeata* var. *valga* in der Lage der beiden maximalen Massenentfaltungen.

Was die Periodizität des Auftretens anderer *Bosmina*-Arten (*B. coregoni*) betrifft, so gibt RUTTNER (1929) in seiner Untersuchung der Lunzer Seen an, dass die Ausbildung der Maxima bei letztgenannter Species vom Jahresgang der Temperatur völlig unabhängig ist.

Wie dem auch sei, erscheint es für eine endgültige Sicherstellung der Periodizität der Planktonorganismen unerlässlich, die Untersuchungen mehrere Jahre hindurch regelmässig fortgesetzt und in Verfolgung eines bestimmten Planes anzustellen. Dies ist besonders dann nötig, wenn es sich um di- oder polyzyklisch auftretende Arten handelt.

In Bezug auf die thermischen Verhältnisse schliesslich scheint das Auftreten von *B. longirostris* in unserem See, wie das des Rädertieres *Anuraea aculeata* var. *valga*, an die verhältnismässig niederen Temperaturen des Jahres gebunden zu sein.

Was die Vertikalverteilung im Laufe des Tages betrifft, so zeigt sie ein verhältnismässig regelmässiges Verhalten. Hier wollen wir als Beispiel eine Serie der Untersuchungen im November anführen.

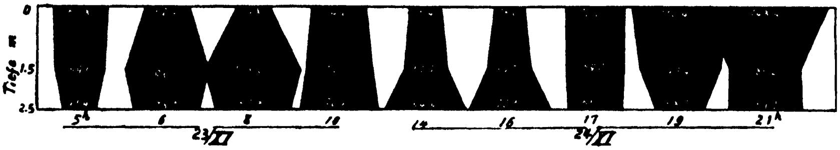


Fig. 18.
Vertikalverteilung von *Bosmina longirostris* (MÜLLER) im Laufe des Tages (23–24 XI, 1929) Sonnenaufgang: 6.16 h. Sonnenuntergang: 17.10 h.

Die Beobachtungen während dieses Monats beginnen ebenfalls um 5 h Morgens; es ist noch dunkel, etwa ein Stunde vor dem Sonnenaufgang.

Die Kurve zeigt, dass um 5 h die maximale Massenentfaltung in der oberflächlichen Wasserschichte gelegen ist.

Im Gegensatz hierzu weist die Verteilungskurve um 6 h ein völlig verändertes Bild auf. Es herrscht noch Morgendämmerung, doch steht der Sonnenaufgang kurz bevor. Eine starke Zunahme der Individuenzahl in der tiefsten Wasserschichte ist unverkennbar, doch fällt die maximale Massenentfaltung in die mittlere Wasserschichte. Es weist also *B. longirostris* mit dem Sonnenaufgang eine Tendenz zur Tiefenbewegung auf.

Dieses Verteilungsverhältnis scheint ohne stärkere Veränderung eine Weile lang fortzudauern, da die Kurve um 8 h im grossen und ganzen mit der um 6 h übereinstimmt, obgleich hier eine schwache Zunahme der Individuenzahl in der tiefsten Wasserschichte erkennbar wird.

Mit der allmählich zunehmenden Beleuchtungsintensität während des hellen Tages schreitet die Abwärtsbewegung weiter fort, wie dies die Verteilungskurven um 10 h, 14 h und 16 h unzweideutig klarlegen. In diesen Kurven tritt die Verlegung der maximalen Bevölkerungsdichte in die tiefste Wasserschichte sehr deutlich zutage, und die Bevölkerungsdichte in der mittleren Wasserschichte ist nun stark zurückgegangen.

Eine plötzliche Veränderung erscheint in der Verteilungskurve um 17 h. Es ist Abenddämmerung, kurz vor Sonnenuntergang. Diese Kurve erweist eine ungefähre Ausgleichung der vertikalen Verteilung in allen Schichten. Dieses Verteilungsverhältnis ist also als Anzeichen einer Aufwärtsbewegung zu beurteilen. Mit dem weiteren Fortschreiten der Nacht wird die Aufwärtsbewegung dieser Species immer stärker, und etwa um 21 h ist die maximale Massenentfaltung in der oberflächlichen Wasserschichte erreicht.

Die vertikale Verteilung von *B. longirostris* scheint demnach in ihrem regelmässigen Tagesgang mit der Lichtintensität in Beziehung zu stehen: es zeigt sich nämlich zuerst eine plötzliche Tiefenbewegung mit dem Sonnenaufgang, welche im Verlaufe des Nachmittags noch mehr zunimmt, und dann eine Aufwärtsbewegung, welche kurz vor Sonnenuntergang einsetzt und mit dem Fortschreiten der Nacht einen immer höheren Grad erreicht.

Geschlechtsverhältnisse: Die Männchen von *B. longirostris* treten in unserem See stets als Begleiter der Weibchen auf, und ihre Anzahl beträgt selbst im günstigsten Falle wenig mehr als ein Drittel der Anzahl der Weibchen. Es herrscht also unbestreitbar Polygynie, zumindest im Beobachtungsjahre.

Wie nachstehende Tabelle zeigt, ist die Individuenzahl der Männchen im März, namentlich verglichen mit der Anzahl im Mai, äusserst gering; der Prozentsatz der Männchen, bezogen auf die Gesamtzahl im gleichen Monat, sinkt hier auf das Minimum.

Die Anzahl der Männchen nimmt dann mit dem allmählich aufsteigenden Temperaturgang des Spätfrühlings plötzlich zu, und erreicht im Mai den maximalen Prozentsatz. Dieser Monat ist zugleich die Periode der maximalen Massenentfaltung von *B. longirostris*. Demnach

Tabelle 4.

Geschlechtsverhältnis von *Bosmina longirostris* (MUELLER) im Laufe des Jahres (III, 1929—I, 1930).

Monat	III 1919	V	VIII	IX	XI	I 1930
♀ pro 5 L.	210	924	133	147	305	558
♂ „ „	40	541	34	50	84	140
♂ % der Gesamtzahl	15.8	36.9	33.8	25.4	21.6	20.0

geht die Massenentfaltung der Männchen mit derjenigen der Weibchen parallel, und die Individuenzahl der Männchen erreicht in diesem Monate das Maximum sowohl nach dem absoluten Wert als auch nach dem Prozentsatz.

Trotz des erstaunlichen Zurückgehens der Individuenzahl im Hochsommer zeigt der Prozentsatz der ♂ ♂ keine auffällige Abnahme, obgleich das Minimum der absoluten Anzahl der ♀ ♀ in diesen Zeitraum fällt.

Etwa von dieser Zeit an bis zum Winter bewegt sich das Produktionsverhältnis der Männchen in einer Richtung, welche dem Verlauf des Periodizitätsdiagramms gerade entgegengesetzt ist: während nämlich die allgemeine Bevölkerungsdichte von *B. longirostris* während dieser Monate mit dem allmählichen Abfall der Temperatur schrittweise zunimmt, zeigt der Prozentsatz der Männchen eine allmähliche Abnahme, trotz der gleichzeitigen stetigen Zunahme der absoluten Individuenzahl der Männchen.

Zusammenfassend kann gesagt werden, dass ein bestimmter Zusammenhang der Geschlechtsverhältnisse mit dem Gang der Periodizität des Auftretens von *B. longirostris* nicht erkennbar erscheint.

Bei dieser Gelegenheit muss allerdings bemerkt werden, dass eine gewisse Schwierigkeit für die Bestimmung des Geschlechtsverhältnisses dieser Species besteht, indem die jungen Weibchen oft schwer von den geschlechtsreifen Männchen zu unterscheiden sind, und daher leicht eine höhere Zahl der letzteren vorgetäuscht werden kann.

Chydorus sphaericus (MÜLLER) 1785.

Chydorus sphaericus ist für gewöhnlich als ein Mitglied der Ufer- oder Moorfauna zu bezeichnen.

In der Tat kommt diese Species in der sumpfigen Uferzone unseres Sees in sehr beträchtlicher Anzahl vor. Ausserdem tritt sie in unserem See häufig in der Profundalregion als Plankter auf, und dazu ist ihr Verhalten in mehrfacher Beziehung von grossem Interesse; sie ist aber zu keiner Zeit als Leitform zu bezeichnen.

Das Auftreten von *Ch. sphaericus* in der Profundalregion wird, wie die Tabelle zeigt, während der heissen Monate—etwa vom Frühsommer bis zum Frühherbst—völlig unterbrochen.

Tabelle 5.

Periodizität des Auftretens von *Chydorus sphaericus* (MÜLLER).
Eingetragen ist die durchschnittliche Individuenzahl für 10 L.

Monat	Uhr / Tiefe (m)	5	6	7	8	9	10	12	14	16	18	19	20	21
III, 1929	0	0	0	0	0	—	—	0	4	—	8	4	2	6
	1.5	0	0	0	0	—	—	0	0	—	0	2	2	6
	2.5	2	0	2	0	—	—	2	2	—	0	2	6	4
V	0	0	0	0	—	0	—	0	0	0	0	4	0	4
	1.5	0	0	0	—	0	—	0	0	0	0	0	0	6
	2.5	0	2	0	—	0	—	0	0	0	2	0	0	4
VIII	fehlt im Plankton völlig													
IX	fehlt im Plankton völlig													
XI	0	0	2	2	2	—	0	0	0	0	0	0	0	0
	1.5	0	0	0	0	—	0	0	0	0	0	0	0	0
	2.5	0	0	0	0	—	0	0	0	0	0	0	0	2
I, 1930	0	2	6	12	—	0	—	0	2	2	12	30	24	30
	1.5	2	2	10	—	2	—	0	2	0	22	38	36	26
	2.5	6	4	12	—	8	—	0	6	2	34	32	26	42

Das Wiedererwachen der Entfaltung scheint etwa im Spätherbst zu beginnen und wird im Zusammenhang mit dem allmählich absteigenden Temperaturgang gegen den Winter stark befördert, um im Januar des folgenden Jahres die maximale Massenentfaltung herbeizuführen.

Im Frühling ist auch ein Zusammenhang der Produktionsverhältnisse dieser Species mit dem Temperaturgang erkennbar. Hierbei erfolgt mit der allmählich aufsteigenden Temperatur gegen den Sommer ein starkes Zurückgehen der Bevölkerungsdichte.

Ch. sphaericus gehört somit zweifelsohne zu den Formen von extrem kalt-stenothermem Verhalten.

Bei dieser Gelegenheit wollen wir weiter die zeitlichen Schwankungen der Vertikalverteilung im Laufe des Tages in Betracht ziehen, da sie durch ein ziemlich regelmässiges Verhalten gekennzeichnet sind.

Betrachtet man die Tabelle, so ist zu ersehen, dass die Individuenzahl in den Serienfängen jedes Monats, im allgemeinen, mit dem Einfallen der Nacht plötzlich zunimmt, und im Gegenteil hierzu während der Tageshelle im Zusammenhang mit der Lichtintensität eine starke Abnahme aufweist; in dieser Beziehung verhält sich also *Ch. sphaericus* wie ein Nachttier.

5. Copepoda.

Diaptomus birulai Rylov 1921.

Diaptomus birulai ist in den Binnengewässern des Flachlandes von Formosa ganz allgemein verbreitet und ist im See Candidius der einzige Vertreter der Diaptomiden, Die Art gehört in unserem See zu den Leitformen von extrem eurythermem Verhalten.

Um die Gesamtverhältnisse der Periodizität dieser Species voll und klar zu verstehen, müssen wir zunächst ihr Auftreten nach den Entwickelungsstadien—Adult, Copepodidstandien und Nauplien—getrennt betrachten.

Adult: Bei Betrachtung des Periodizitätsdiagramms fällt es auf, dass die Bevölkerungsdichte während der Frühlingsmonate keine auffällige Veränderung aufweist.

Ein starkes Zurückgehen der reifen Tiere scheint erst im Frühsommer zu beginnen, um etwa im Hochsommer zu ihrem völligen Verschwinden aus dem Plankton zu führen. Doch soll damit nicht gesagt sein, dass geschlechtsreife Individuen damals absolut gefehlt haben, da die quantitativen Schöpffänge in diesem Monate an Zahl sehr gering waren, und anderseits die Netzfänge eine spärliche Menge von geschlechtsreifen oder selbst eiertragenden Weibchen enthielten.

Weiter ist zu bemerken, dass in diesem Monat (Juli) die Proben während der Mittagszeit entnommen wurden. Die Mittagsstunden sind aber insofern ungünstig, als die geschlechtsreifen Tiere, wie noch im Abschnitt über die Vertikalverteilung näher ausgeführt werden soll, bei intensiver Beleuchtung eine ausgeprägte Tiefenbewegung zeigen, und es daher wohl möglich ist, dass sie sich völlig in das Gebiet ausserhalb des Bereichs der Schöpffänge zurückgezogen hatten. Immerhin besteht kein Zweifel, dass die Bevölkerungsdichte der reifen Tiere in diesem Monate das Minimum erreicht.

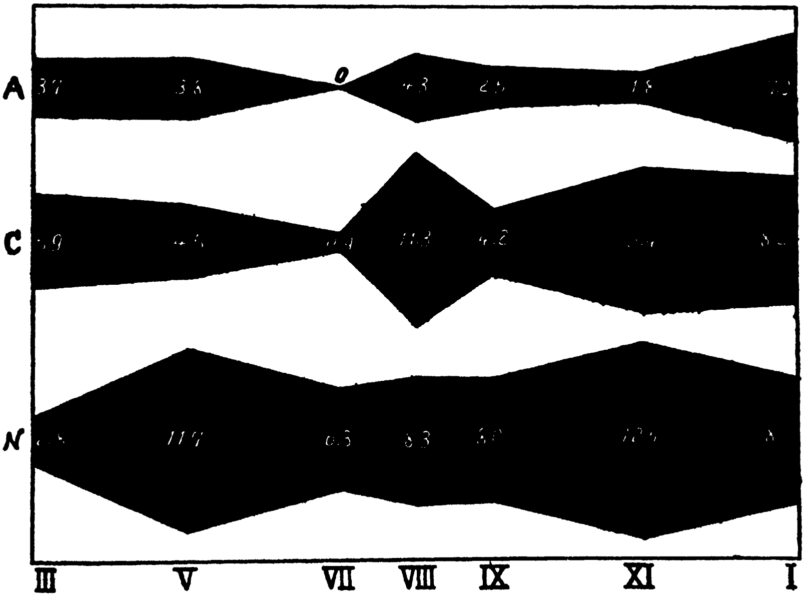


Fig. 19.

Periodizitätsdiagramm von *Diaptomus birulai* RYLOV im Laufe des Jahres (III, 1929–I, 1930). A...Adult, C...Copepodidstadien, N...Nauplien.

Auf diese Periode des Minimums folgt ein plötzlicher Aufstieg der Volksdichte, welcher im August zur ersten maximalen Massenentfaltung führt.

Von dieser Zeit an geht die Bevölkerungsdichte allmählich wieder zurück und das zweite Minimum entsteht im Spätherbst.

Eine sehr ausgeprägte Entwickelung der reifen Tiere beginnt dann mit dem Eintritt der Wintermonate, und die zweite maximale Massenentfaltung zeigt sich im Januar, wo die Individuenzahl durchschnittlich 7 pro 1 L. beträgt. Ein Zusammenhang der Periodizität der reifen Tiere mit dem Jahresgang der Wassertemperatur ist also nicht sicher erkennbar.

Was das Verhältnis der Geschlechter betrifft, so weist *D. birulai* im Laufe des Jahres ziemlich auffallende Schwankungen auf. Das Männchen kommt, wie man annehmen darf, auch in unserem See stets als Begleiter der Weibchen das ganze Jahr hindurch vor.

Tabelle 6.

Periodizitat des Gechlechtsverhaltnisses von *Diaptomus birulai* RYLOV im Laufe des Jahres.

Monat	III 1929	V	VIII	IX	XI	I 1930
♀	264	364	426	248	178	538
♂	294	266	425	199	164	602
♂ % der Gesamtzahl	52.6	42.1	50.0	44.3	48.2	52.7

Die Tabelle zeigt, dass die Periodizität des Männchens zwei Maxima aufweist, eines im März und eines im Januar. Die Periodizität des Auftretens der Männchen stimmt also im grossen und ganzen mit der der Weibchen überein.

Weiterhin ist zu bemerken, dass die Männchen in ihrer maximalen Massenentfaltung die Zahl der Weibchen nahezu erreichen oder sogar schwach überwiegen. Eine solche leichte Polyandrie entsteht in unserem See in den kälteren Monaten. In thermischer Hinsicht ist demnach eine Regelmässigkeit erkennbar, indem die Periodizität der Männchen hauptsächlich von dem Jahresgang der Temperatur abhängt. Die Tabelle lässt nämlich erkennen, dass gegen die Wintermonate, und im Zusammenhang mit dem absteigenden Temperaturgang, eine Zunahme des Prozentsatzes der Männchen erfolgt, während mit dem aufsteigenden Temperaturgang im Frühling im Gegenteil eine Abnahme desselben eintritt.

Die Ausgleichung der beiden Geschlechter im August steht aber ausser dieser Regelmässigkeit.

Copepodidstadien: Die Copepodidstadien von *D. birulai* fehlen in unserem See zu keiner Jahreszeit im Plankton. Das erste Minimum fällt, wie bei den geschlechtsreifen Tieren, in den Juli, nach einem allmählichen Zurückgehen während des Frühlings und Frühsommers.

Darauf folgt sodann eine plötzliche Zunahme der Bevölkerungsdichte, um im Spätsommer das zweite, sehr ausgeprägte Maximum zu erreichen; dieses Verhältnis stimmt ebenfalls völlig mit dem der geschlechtsreifen Tiere überein.

Das zweite Minimum kommt durch das plötzliche Zurückgehen im September zustande. Auf dieses zweite Minimum folgt zunächst ein Wiedererwachen der Entfaltung der Copepodidstadien, und das zweite Maximum wird im Spätherbst erreicht.

In der späteren Jahreszeit, nämlich während der Wintermonate, weist die Bevölkerungsdichte der Copepodidstadien ein allmähliches Zurückgehen auf. Es besteht also eine offenbare Reziprozität zwischen den Copepodidstadien und den geschlechtsreifen Tieren.

Nauplien: In unserem See geht die Fortpflanzung von *D. birulai* das ganze Jahr hindurch ohne Pause vor sich, und das Periodizitätsdiagramm der Nauplien stellt sich demgemäss als ein nirgends unterbrochenes Bild dar.

Im Periodizitätsdiagramm der Nauplien bemerkt man zwei Maxima, eines im Mai und eines im November, und weiter zwei Minima, ein sehr ausgeprägtes im März und ein weniger auffälliges in den Sommermonaten.

Eine nähere Betrachtung der Periodizität der Nauplien macht es wahrscheinlich, dass die optimale Massenentfaltung, d. h. die maximale Eierablage, an die mässig niederen Temperaturen im Frühling und Herbst gebunden ist. Ein weiterer Zusammenhang mit der Temperatur ist dagegen nicht zu erkennen, indem die zwei Maxima in thermisch völlig entgegengestzte Jahreszeiten fallen.

Zusammenfassend muss gesagt werden, dass *D. birulai* einen Zusammenhang der Periodizität mit dem thermischen Milieufaktor nicht erkennen lässt und demnach als eine extrem eurytherme Form zu bezeichnen ist. Die Eierablage dauert bei *D. birulai* das ganze Jahr hindurch ununterbrochen fort.

Vertikalverteilung:

Es ist schon von verschiedenen Autoren festgestellt worden, dass die Copepoden-Arten täglich zweimal eine Aufwärtsbewegung, eine während der Morgen-, die andere in der Abenddämmerung, ausführen. Es scheint am besten, die Vertikalverteilung der einzelnen Entwicklungsstadien—Adult, Copepodidstadien und Nauplien—diesmal auch getrennt zu betrachten.

Adult: Die geschlechtsreifen Tiere von *D. birulai* weisen in ihrer Vertikalverteilung im Laufe des Tages in allen Beobachtungsmonaten ungefähr dasselbe Bild auf. Als Beispiel mögen die Beobachtungsresultate im November 1929 dienen.

Aus der Verteilungskurve ergibt sich sofort, dass die reifen Tiere im Rahmen der Beobachtungszeit von 5 h—21 h sicher eine zweimalige Aufwärtsbewegung ausführen.

Eine ausgeprägte Massenentfaltung an der Oberfläche ist in der Kurve zuerst um 6 h, also am noch dämmerigen Frühmorgen erkennbar. Dazu ist jedoch zu bemerken, dass die maximale Massenentfaltung schon in der mittleren Wasserschichte liegt, dass also dieser Zeitpunkt sicher nicht als Kulmination der Aufwärtsbewegung betrachtet werden kann.

Mit dem Sonnenaufgang folgt eine sehr deutliche Tiefenbewegung. Um 7 h finden wir schon einen starken Abfall an der Oberfläche und dementsprechend eine auffällige Zunahme sowohl in der mittleren als auch in der tiefsten Wasserschichte.

Je weiter der Tag fortschreitet, desto spärlicher wird allmählich die Bevölkerungsdichte an der Oberfläche, und zuletzt, während 14 h–16 h, verschwinden die geschlechtsreifen Tiere völlig aus der oberflächlichen Wasserschichte.

Während der Tageshelle geht auch die Volksdichte in der mittleren Wasserschichte auffallend zurück; und die maximale Massenentfaltung findet sich in der tiefsten Wasserschichte, unmittelbar über dem Seegrund.

Eine plötzliche Aufwärtsbewegung setzt wieder gegen Abend ein. Schon um 17 h treten reife Tiere wieder in der oberflächlichen Wasserschichte auf, und weiter findet eine Zunahme der Individuenzahl in der mittleren Wasserschichte statt. Um diese Stunde ist die Sonne schon hinter dem dem See im Westen vorgelagerten Hügel untergegangen.

Die maximale Volksdichte an der Oberfläche aber wird erst später erreicht, etwa um 19 h, also etwa zwei Stunden nach Sonnenuntergang.

Von dieser Periode an beginnt wieder ein Abfall an der Oberfläche im Zusammenhang mit der fortschreitenden Nacht.

Kurz gesagt, die geschlechtsreifen Tiere von *D. birulai* zeigen innerhalb der Beobachtungzeit sicher zweimal eine Aufwärtsbewegung, einmal am Frühmorgen, und dann wieder spät am Abend. Die besten Milieu-Bedingungen für die geschlechtsreifen Individuen während des hellen Tages scheinen sich in der tiefsten Wasserschichte, dicht über dem Seegrunde, zu finden.

Copepodidstadien: Ganz andere Verhältnisse der Vertikalverteilung im Laufe des Tages weisen die Copepodidstadien auf.

Aus der Vertikalverteilung ersieht man, dass die Copepodidstadien täglich dreimal Aufwärtsbewegungen ausführen, obgleich dieselben nicht sehr ausgeprägt sind.

Die erste Aufwärtsbewegung findet sicher am Tagesanbruch statt, wenn sie auch nur schwach erkennbar ist.

Mit Sonnenaufgang geht aber die Bevölkerungsdichte an der Oberfläche plötzlich zurück und es erfolgt eine lebhafte Anhäufung in der mittleren Wasserschichte. Die Tiefenbewegung schreitet weiter fort, und zwischen 6 h und 10 h zeigt sich eine starke Massenentfaltung in der tiefsten Wasserschichte.

Die Vertikalverteilung der Copepodidstadien bietet nun während der Mittagsstunden die interessante Erscheinung dar, dass um diese Zeit wieder eine starke Zunahme der Individuenzahl an der Oberfläche, und dementsprechend eine ausgeprägte Abnahme in der tiefsten Wasserschichte stattfinden.

Diese Verteilung ist ebenfalls als eine Aufwartsbewegung zu bezeichnen, welche um Mittag fur die Jungtiere charakteristisch ist und sich auch bei den Nauplien findet, niemals aber bei den reifen Tieren, welche im Gegenteil einen negativen Heliotropismus wahrend der Tageshelle aufweisen.

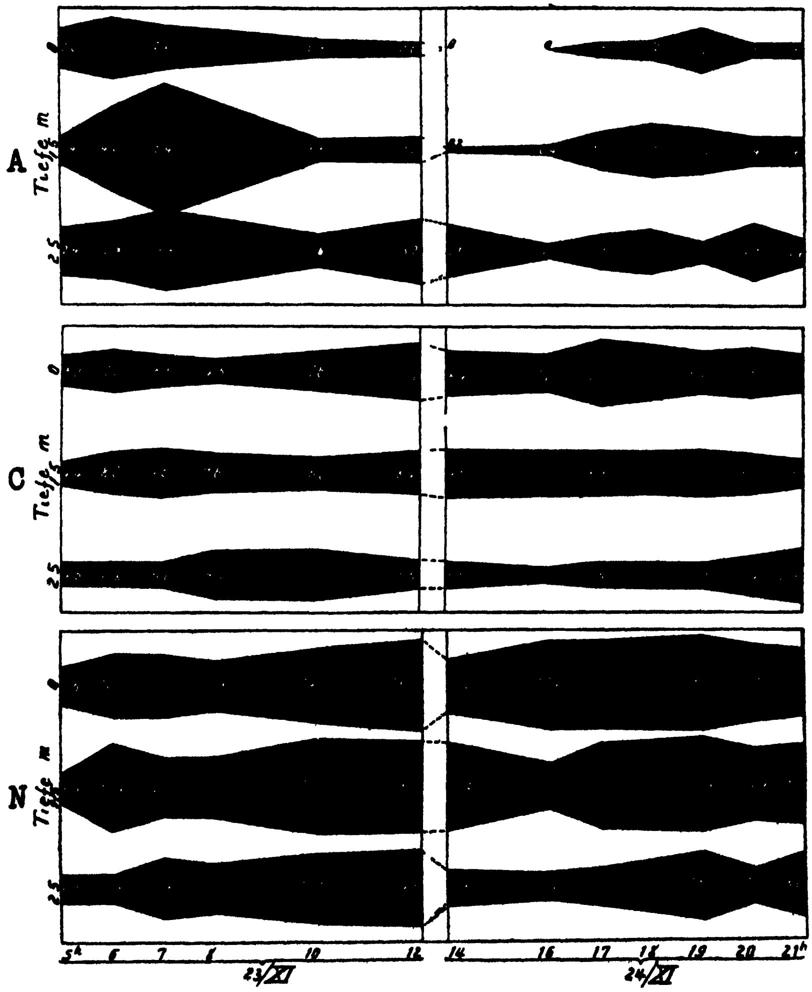


Fig. 20.

Vertikalverteilung von *Diaptomus birulai* RYLOV im Laufe des Tages (23-24 XI, 1929) Sonnenaufgang: 6.16 h, Sonnenuntergang: 17.10 h. A...Adult, C...Copepodidstadien, N...Nauplien.

Die Copepodidstadien scheinen auch für den Sonnenuntergang empfindlich zu sein und eine dritte Aufwärtsbewegung ist gegen Abend erkennbar. Mit dem Fortschreiten der Nacht geht jedoch eine allmähliche Tiefenbewegung vor sich.

Nauplien: Was die Vertikalverteilung der Nauplien im Laufe des Tages anbetrifft, so bemerkt man etwa dieselben Verhältnisse wie bei den Copepodidstadien.

Wenn man nur die Schwankungen in der oberflächlichen Wasserschichte in Betracht zieht, so ist ebenfalls eine dreimalige Aufwärtsbewegung, die erste am Frühmorgen, die zweite am Mittag und die dritte am Abend, zu erkennen.

Noch ist zu bemerken, dass die Nauplien sich hauptsächlich in der oberflächlichen Wasserschichte zusammendrängen und die Bevölkerungsdichte in der tiefsten Wasserschichte stets sehr gering ist.

Mesocyclops thermocyclopoides HARADA 1931.

Mesocyclops thermocyclopoides ist in unserem See eine dominierende Species, welche zu allen Jahrezeiten in der Profundalregion auftritt und eine Hauptkomponente des Zooplanktons ausmacht.

Periodizität.

Adult: Das Auftreten der geschlechtsreifen Tiere von *M. thermocyclopoides* lässt während unserer Beobachtungszeit drei Perioden der Massenentfaltung erkennen, von denen die erste, sehr schwach ausgebildete in den Mai, die zweite, deutlich ausgeprägte in den September, und die dritte in den Januar fällt.

Obgleich die Minima der Bevölkerungsdichte im März und im November nur sehr schwach ausgebildet sind, ist das Minimum im Hochsommer so ausgeprägt, dass man in dieser Periode von einem nahezu völligen Fehlen der geschlechtsreifen Tiere im Plankton sprechen kann. Dieses ausserordentlich spärliche Auftreten von reifen Individuen im Hochsommer stimmt mit dem bei *Diaptomus birulai* beobachteten Verhältnis völlig überein.

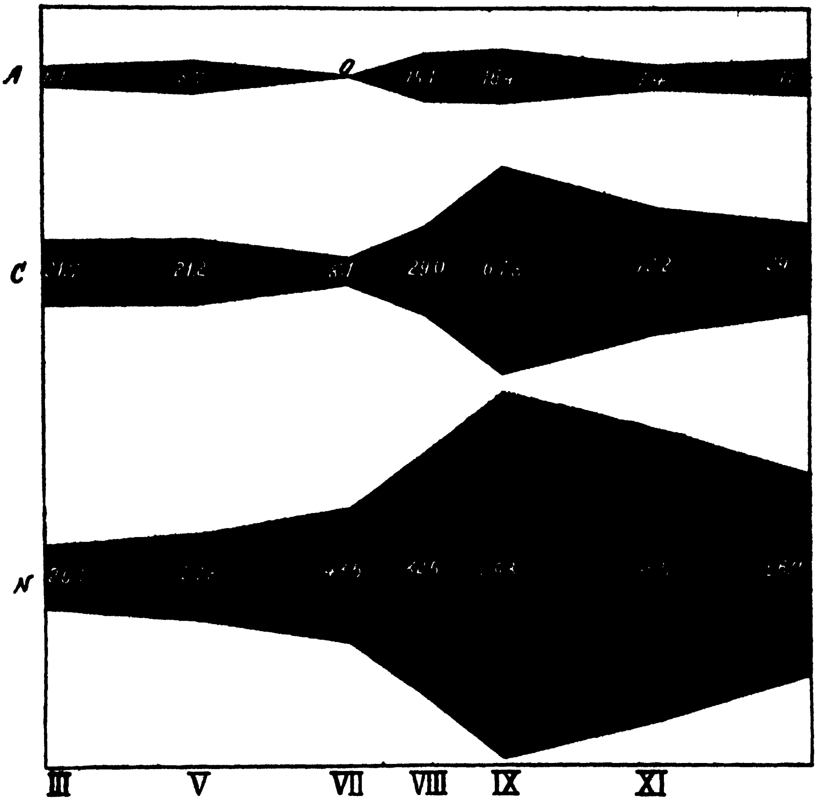


Fig. 21
Periodizitatsdiagramm von *Mesocyclops thermocyclopoides* HARADA im Laufe des Jahres (III, 1929–I, 1930). A Adult, C . Copepodidstadien, N...Nauplien.

Geschlechtsverhaltnis: *M. thermocyclopoides* ist in unserem See im Hochsommer von ausserordentlich sparlichem Auftreten, bringt aber zu allen anderen Jahreszeiten zugleich Männchen und Weibchen hervor. Was das Verhaltnis der Geschlechter anbelangt, so ist es aus der folgenden Tabelle wohl zu erkennen.

Die Tabelle zeigt vor allem, dass zu allen Jahreszeiten mit alleiniger Ausnahme des Spätherbstes die Männchen den Weibchen gegenüber bei weitem vorwiegen. Wir dürfen also annehmen, dass Polyandrie für *M. thermocyclopoides* in unserem subtropischen See die Regel bildet.

Man sieht ferner, dass die Hochproduktion der geschlechtsreifen Tiere stets von einer solchen des Männchens begleitet wird, wie dies auch bei *Diaptomus birulai* der Fall ist.

Tabelle 7.

Geschlechtsverhältnisse von *Mesocyclops thermocyclopoides* HARADA im Laufe des Jahres (III, 1929–I, 1930).

Monat	III 1929	V	VII	VIII	IX	XI	I 1930
♀	395	651	ausserordentlich spärlich	1257	1126	779	813
♂	513	781		1697	1827	664	856
♂ % der Gesamtzahl	56.6	54.4		57.6	61.8	46.0	51.2

Weiter ist zu bemerken, dass das Maximum beider Geschlechter zusammen im September einzig und allein auf der starken Zunahme der Männchen beruht, wie aus der Tabelle deutlich hervorgeht; die maximale Bevölkerungsdichte der Weibchen fällt wesentlich in den August, und im September ist vielmehr ein entscheidender, wenn auch nicht sehr starker Abfall erkennbar.

Auf diese ausgeprägte Polyandrie folgt ein plötzliches Zurückgehen der Männchen gleichzeitig mit einem solchen der Weibchen und führt im November, im Gegensatz zu dem bisherigen Verhältnis, zu einer Polygynie, welche wir indes innerhalb unserer Beobachtungsperiode nur dieses eine mal beobachtet haben.

Copepodidstadien: Gegenüber dem so komplizierten Auftreten der geschlechtsreifen Tiere im Laufe des Jahres weisen die Copepodidstadien eine einfache Periodizität, nämlich eine nur einmalige maximale Massenentfaltung auf.

Die minimale Bevölkerungsdichte fällt jedoch, wie bei den reifen Tieren, ebenfalls in den Hochsommer.

Infolge der plötzlichen Zunahme im Spätsommer wird die maximale Massenentfaltung schon im Frühherbst erreicht; hier zeigt sich demnach eine Übereinstimmung mit den geschlechtsreifen Tieren.

Hierauf folgt dann im Zusammenhang mit dem absteigenden Temperaturgang gegen den Winter ein allmählicher Abfall. Dieser Rückgang scheint bis zum Hochsommer des folgenden Jahres fortzudauern, da die Bevölkerungsdichte im Januar (1930), wie man aus dem Periodizitätsdiagramm entnehmen kann, mit der im März (1929) in ununterbrochenen Zusammenhang gesetzt werden kann.

Nauplien: Das Periodizitätsdiagramm der Nauplien stellt, wie bei den Copepodidstadien, ebenfalls ein einfaches, aber selbständiges Bild dar. Die maximale Bevölkerungsdichte wird im Frühherbst erreicht, übereinstimmend mit jener der geschlechtsreifen Tiere.

Die Bevölkerungsdichte im Beginn des Frühlings ist sehr gering und sinkt zu dieser Zeit auf das Minimum.

Die Nauplien, welche während des Frühlings und Frühsommers eine nur sehr langsame Zunahme aufweisen, zeigen nun im Spätsommer eine sehr ausgeprägte Entfaltung, um im Frühherbst das Maximum zu erreichen.

Etwa von dieser Zeit an geht die Individuenzahl der Nauplien im Zusammenhang mit dem absteigenden Temperaturgang gegen den Winter hin allmählich zurück. Aus all diesem folgt, dass *M. thermocyclopoides* als eine extrem eurytherme Form zu bezeichnen ist, und weiter, dass die Eierablage das ganze Jahr hindurch ununterbrochen fortdauert.

Hierzu ist noch zu bemerken, dass der Verlust an Individuen während der Entwickelungsperiode dieser Species einen ganz erstaunlichen Umfang zu erreichen scheint.

Vertikalverteilung.

In Ubereinstimmung mit dem Verhalten der Copepoden im allgemeinen zeigen die geschlechtsreifen Tiere von *M. thermocyclopoides* gleichfalls eine sehr ausgeprägte Aufwärtsbewegung am Frühmorgen und am Abend.

Wir haben also zunächst eine kurze Darstellung der Verteilungskurve der reifen Tiere, zugleich auch der Copepodidstadien und weiter der Nauplien zu geben.

Die Aufwärtsbewegung der reifen Tiere beginnt, wie die Kurve zeigt, schon am frühen Morgen, noch vor Tagesanbruch, und die maximale Massenentfaltung an der Oberfläche wird kurz nach Sonnenaufgang erreicht.

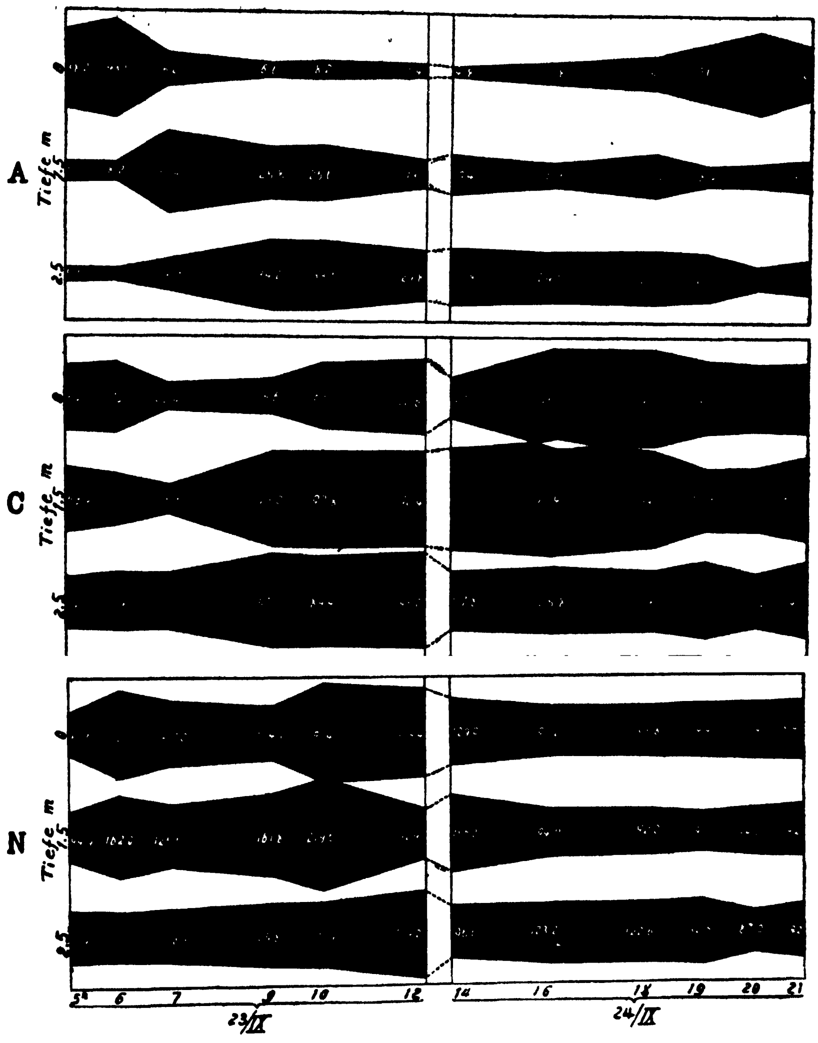


Fig. 22.
Vertikalverteilung von *Mesocyclops thermocyclopoides* HARADA im Laufe des Tages (23–24 IX, 1929). Sonnenaufgang: 5.45 h. Sonnenuntergang: 17.55 h. A...Adult, C...Copepodidstadien, N...Nauplien.

Mit dem völligen Eintritt der Tageshelle jedoch ändert sich das Verteilungsverhältnis sehr plötzlich. Es kommt nämlich schon um 7 h zu einem starken Abfall an der Oberfläche und dementsprechend zu einer erstaunlichen Anhäufung in der mittleren Wasserschichte.

Die Bevölkerungsdichte sowohl in der oberflächlichen als auch in der mittleren Wasserschichte geht dann mit fortschreitender Tageshelle allmählich zurück, und die stärkste Anhäufung wird in die tiefste Wasserschichte verlegt, ungefähr wie bei *Diaptomus birulai*. Es zeigt sich jedoch ein gewisser Unterschied zwischen den zwei Arten, indem die geschlechtsreifen Tiere von *D. birulai* am hellen Tage häufig völlig aus der Oberflächenschicht verschwinden, während die von *M. thermocyclopoides* in der Regel noch in ziemlicher Anzahl überbleiben.

Die Aufwärtsbewegung am Abend beginnt, wenn auch anfänglich schwach, schon bei Sonnenuntergang, doch wird die maximale Massenentfaltung an der Oberfläche erst am späten Abend erreicht.

Was die Vertikalverteilung der Copepodidstadien anbelangt, so ist eine ungefähre Übereinstimmung derselben mit jener von *D. birulai* zu erkennen.

Betrachtet man nur die Schwankungen der Individuenzahl an der Oberfläche, so ist sofort zu ersehen, dass auch die Copepodidstadien dieser Species eine täglich dreimalige Aufwärtsbewegung, die erste am frühesten Morgen, die zweite etwa am Mittag und die dritte am frühen Abend ausführen. In der mittleren Wasserschichte findet während der Tageshelle eine sehr ausgeprägte Anhäufung statt, und eine Ausgleichung der Vertikalverteilung wird am späten Abend herbeigeführt.

Was die Nauplien anbetrifft, so herrschen etwa dieselben Verteilungsverhältnisse wie bei den Copepodidstadien.

Obgleich die Aufwärtsbewegung am Frühmorgen und am Mittag deutlich ausgeprägt ist, ist die am Abend kaum zu erkennen, und die Vertikalverteilung der Nauplien während des Morgens ist, im Vergleich mit jener während des Nachmittags, sehr schwankend.

Eucyclops (Tropocyclops) prasinus candidiusi HARADA 1931

Eine kleinste Copepoden-Art; *E. (T.) prasinus candidiusi* ist auch als Dauerform zu bezeichnen, da sie in unserem See in der Pelagischen zone jederzeit vorkommt.

Ihr Auftreten im Frühjahre ist auffallend spärlich und das Minimum

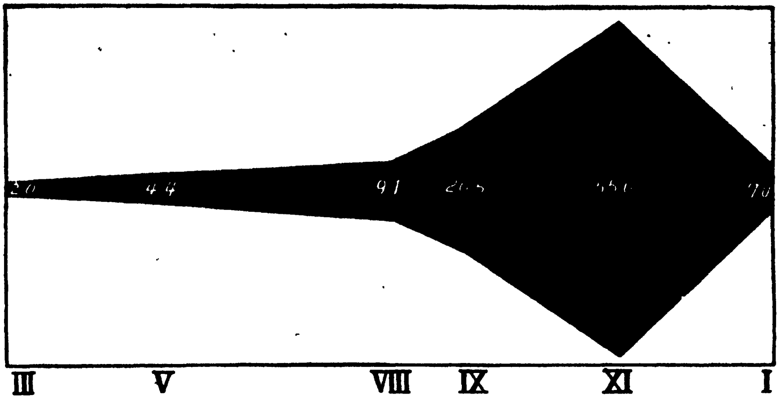


Fig. 23.

Periodizitatsdiagramm von *Eucyclops* (*Tropocyclops*) *prasinus candidiusi* HARADA im Laufe des Jahres (III, 1929—I, 1930). Die Ordinaten bezeichnen die durchschnittliche Individuenzahl pro 10 L. in jedem Monate, und entsprechen der Gesamtzahl der jungen und reifen Tiere.

wird im März erreicht. Darauf folgt eine sehr langsame Vermehrung bis zum August. Die lebhafte Fortpflanzung beginnt erst im September, und führt zuletzt im November zu einer maximalen Massenentfaltung. In letzterem Monat besteht aber die Mehrzahl (etwa 77 %) der Population aus Jungen, und demnach ist es wohl möglich, dass die aktuelle maximale Massenentfaltung der reifen Tiere vielleicht noch später erreicht wird.

Das Zurückgehen scheint dagegen viel plötzlicher zu sein, da die Bevölkerungsdichte schon im Spätwinter sehr gering wird.

Tabelle 8.

Geschlechtsverhältnisse von *Eucyclops* (*Tropocyclops*) *prasinus candidiusi* HARADA im Laufe des Jahres (III, 1929—I, 1930).

Monat	III 1929	V	VIII	IX	XI	I 1930
♀	9	21	39	31	154	15
♂	8	8	24	21	95	6
♂ % der Gesamtzahl	47.0	27.6	38.1	40.4	38.1	28.6

Was das Verhältnis der Geschlechter betrifft, so scheint bei vorliegender Species in unserem See stets Polygynie zu herrschen. Polyandrie, welche so häufig bei *Diaptomus birulai* und *Mesocyclops thermocyclopoides* vorgefunden wird, ist bei vorliegender Species während der Beobachtungszeit niemals gefunden worden.

Während der maximalen Massenentfaltung beträgt der Prozentsatz der Männchen 38.1% der Gesamtzahl der reifen Tiere.

6. Ostracoda.

Cypria javana Müller 1906.

Cypria javana stellt in unserem See eine typische Form der Bodenfauna dar; ihr Auftreten im freien Wasser ist bei der Seichtigkeit des Sees, abgesehen von den sehr jungen Stadien, völlig auf die Nacht beschränkt, da sie sich während des hellen Tages fast immer in den Bodenschlamm eingräbt.

Wenn zwar *C. javana* ebenfalls als Dauerform zu bezeichnen ist, zeigt sich doch auch in ihrem Auftreten eine jährliche Schwankung, welche wir zunächst schildern wollen.

Im folgenden Periodizitätsdiagramm bezeichnen die Ordinaten die durchschnittliche Individuenzahl pro 1 L., welche wir in jedem Monate aus meistens drei Proben (entnommen um 19, 20 und 21 h) berechnet haben; nur im Mai haben wir uns auf zwei Proben (entnommen um 20 und 21 h) beschränkt, weil das Auftreten von *C. javana*, wie später näher darstellt wird, am frühesten Abend sehr lebhaft ist.

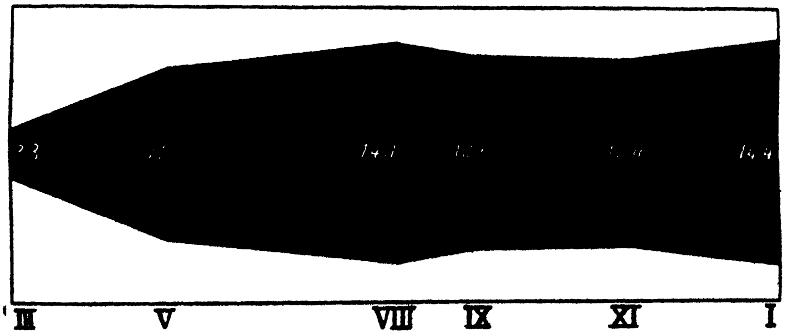


Fig. 24.
Periodizitätsdiagramm von *Cypria javana* MÜLLER im Laufe des Jahres (III, 1929—I, 1930).

C. javana weist in ihrem Auftreten im Laufe des Jahres zwei Maxima auf, von denen eines in den August und eines in den Januar fällt.

Wie das Periodizitätsdiagramm zeigt, ist die Bevölkerungsdichte im Beginn des Frühlings sehr gering und erreicht hier das Minimum.

Die erste maximale Massenentfaltung wird, nach allmählicher Zunahme während des Frühlings und Frühsommers, im Spätsommer erreicht. Die zweite fällt dagegen in den tiefen Winter, ist aber von der ersten nur durch ein sehr schwach erkennbares Zurückgehen während des Herbstes geschieden.

Die Lage der Fortpflanzungsperioden von *C. javana* ist mit Sicherheit nicht festzustellen, weil, wie die Tabelle zeigt, die Jugendstadien in unserem See zu keiner Jahreszeit im Plankton fehlen. Es scheint jedoch, dass die Hauptproduktion der Jugendstadien in den Spätsommer und auch noch in den tiefen Winter fällt, und dass diese Periodizität ungefähr mit der der voll entwickelten Tiere parallel geht.

Wir wollen damit keineswegs behaupten, dass *C. javana* in unserem See jährlich nur zwei Generationen besitzt, da unsere Untersuchungen in dieser Beziehung nicht eingehend genug sind; für die Entscheidung dieser Frage wäre weiter die Untersuchung des Bodenschlammes, welche wir niemals unternommen haben, absolut erforderlich.

Bei dieser Gelegenheit ist aber beizufügen, dass das Auftreten der Jungtiere immer auffallend spärlich ist; wenn sie überhaupt vertreten sind, beträgt ihre Zahl kaum jemals mehr als 0.4 pro 1 L., wogegen die Zahl der Geschlechtsreifen nicht selten auf 20–25 pro 1 L. ansteigt. Weiter ist zu bemerken, dass die Jungtiere hauptsächlich während des hellen Tages auftreten.

Vertikalverteilung:

Die Vertikalverteilung von *C. javana* ist in Tabelle 9 ausführlich dargestellt. Diese Species ist, wie schon oben erwähnt, als ein typisches Nokturntier zu bezeichnen, da sie während des hellen Tages ihren Wohnort im Bodenschlamm sucht.

Das Auftreten dieser Species im freien Wasser, d. h. ihre Aufwärtsbewegung, beginnt etwas nach Sonnenuntergang und die maximale Massenentfaltung wird etwa zwei Stunden nach Sonnenuntergang erreicht.

Tabelle 9.

Vertikalverteilung von *Cypria javana* MÜLLER im Laufe des Jahres. Die Zahlen fur jede Tiefe bezeichnen die Individuenzahl pro 1 L. des Seewassers. Die Zahlen fur die Jugendstadien sind **fett** gedruckt.

	Uhr Tiefe (m)	5	6	7	8	9	11	12	14	16	17	18	19	20	21
Marz, 1929	0	1.2	0	0	0			0	0		0	0	3.0	2.2	1.8
	1.5	0.2	0	0	0			0	0		0	0.6	6.6	5.0	1.4
	2.5	0.2	0	0.2	0			0	0.2		0	1.2	2.8	2.4	4.2
	S.	1.6		0.2					0.2			1.8	12.4	9.6	7.4
	Sonnenaufgang: 5.55 h Sonnenuntergang: 18.10 h														
Mai	0	0	0	0		0		0	0	0		0	3.4	8.6	10.4
	1.5	1.0 (0.2)	0.2	0		0		0	0	0		0	0.8	14.8	9.0
	2.5	0	0	0		0		0	0	0		0	0	6.2	16.8
	S.	1.0	0.2										4.2	29.6	36.2
	Sonnenaufgang: 5.11 h Sonnenuntergang: 18.38 h														
August	0	0.6	0	0	0	0	0				0	0	12.2	14.0	18.2
	1.5	0	0	0	0	0	0				0	0.2	9.6	17.8	14.2
	2.5	0	0	0	0	0.2	0.2				0	0	6.6	18.4	15.6
	S.	0.6				0.2	0.2					0.2	28.4	50.2	48.0
	Sonnenaufgang: 5.35 h Sonnenuntergang: 18.25 h														
September	0	0	0.2	0.4		0		0	0	0		0	18.6	14.6	10.2
	1.5	0	0.2	0		0		0.2	0	0		0	24.4	12.2	13.2
	2.5	2.0	0	0		0		0	0	0		0.2	7.2	7.2	6.0
	S.	2.0	0.4	0.4				0.2				0.2	50.2	34.0	29.4
	Sonnenaufgang: 5.45 h Sonnenuntergang: 17.55 h														
November	0	0.4	0	0	0.2			0	0	0	0	9.8	17.2	11.6	15.4
	1.5	3.2	0	0	0.2			0	0	0	0	5.4	14.0	7.2	12.8
	2.5	3.8	0	0	0			0	0.2	0	0	10.2	8.6	13.0	7.8
	S.	7.4			0.4				0.2			25.4	39.8	31.8	36.0
	Sonnenaufgang: 6.15 h Sonnenuntergang: 17.10 h														
Januar, 1930	0	3.8 (0.2)	2.6	0		0		0	0	0		0	14.2	19.6	10.2
	1.5	3.4 (0.2)	7.8	0		0		0	0	0		0.2	13.2 (0.2)	14.6	12.6
	2.5	8.0 (0.2)	4.6	0.2		0.4		0.2	0.4	0		0.6 (0.2)	20.4	10.2	14.4
	S.	15.2	15.0	0.2		0.4		0.2	0.4			0.8	47.8	44.4	37.2
	Sonnenaufgang: 6.41 h Sonnenuntergang: 17.38 h														

Es kommt ferner vor, dass die Bevölkerungsdichte mit dem Fortschreiten der Nacht allmählich zurückgeht; dies gilt wahrscheinlich für jeden Monat.

Schon am frühesten Morgen, während es noch dunkel ist, zeigt es sich, dass die Bevölkerungsdichte in allen Wasserschichten stark zurückgegangen ist, und bei Tagesanbruch sind keine Tiere mehr im freien Wasser zu finden. Wenn hier also eine Vermutung erlaubt ist, so ist das Auftreten der *C. javana* im freien Wasser am späteren Abend am lebhaftesten, und geht allmählich im Laufe der Nacht zurück, bis zuletzt am Frühmorgen nur noch eine sehr geringe Bevölkerungsdichte zu beobachten ist.

Zusammenfassend kann gesagt werden, dass *C. javana* sich durch eine ziemlich regelmässige tägliche Abwärts- und Aufwärtsbewegung auszeichnet. Dies bezieht sich jedoch ausschliesslich auf die voll entwickelten Tiere; im Gegensatz hierzu sind die kleinen Jungtiere in ihrem Auftreten sehr unregelmässig.

7. Diptera.

Corethra-Larven.

Die *Corethra*-Larven sind in unserem See, wie *Cypria javana*, typische Bodenbewohner. Wie allgemein bekannt, sind die *Corethra*-Larven negativ phototropisch. Neuerdings hat D. MIYADI, gelegentlich seiner Untersuchungen verschiedener Seen Japans, eingehende Angaben über das Auftreten von *Corethra*-Larven geliefert. Nach ihm treten sie in den tieferen Seen am hellen Tage nur in der tiefsten Wasserschichte, z. B. im Sumiyoshi-Ike in Tiefen von mehr als 12 m, im See Yogo in Tiefen von mehr als 6 m auf; dabei nimmt die Individuenzahl, im allgemeinen, mit der Tiefe allmählich zu. Dies gilt aber nur für tiefe Seen; in unserem so seichten See liegen die Verhältnisse natürlich verschieden. In unserem See sind die *Corethra*-Larven nur während der Nachtzeit im freien Wasser zu finden und graben sich während des hellen Tages in den Bodenschlamm ein.

Zunächst wollen wir die jährliche Schwankung in Betracht ziehen. Da wir keine Proben des Bodenschlammes entnommen haben, so bezieht sich die im folgenden Diagramm angegebene Bevölkerungsdichte in jedem Monate nur auf die dreimaligen Schöpffänge (um 19, 20 und 21 h).

Aus dem Periodizitätsdiagramm ist zu ersehen, dass die maximale Massenentfaltung jährlich nur einmal, im September, stattfindet, wie dies auch in vielen Seen Japans (MIYADI), im Plus-See zu Plön (LUNDBECK) und im See Mendota in Wisconsin der Fall ist.

Die Individuenzahl in diesem Monat beträgt durchschnittlich 11.6, doch erreicht die aktuelle Höchstzahl 30.0 pro 1 L.

Die Bevölkerungsdichte nimmt dann gegen den Winter allmählich ab, doch überleben die Larven gewöhnlich in ziemlicher Anzahl den Winter, um im Frühjahr auf das Minimum zurückzugehen.

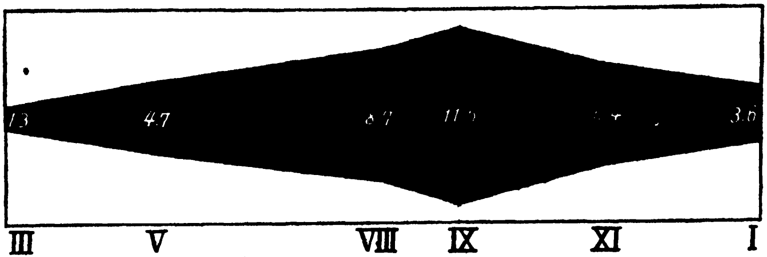


Fig. 25.
Periodizitatsdiagramm der *Corethra*-Larven im Laufe des Jahres (III, 1929—I, 1930). Die Ordinaten bezeichnen die durchschnittliche Individuenzahl pro 10 L. des Seewassers.

Hier sei bemerkt, dass nach MIYADI die Bevölkerungsdichte der *Corethra*-Larven in den Seen Südjapans (z. B. Sumiyoshi-Ike usw.) je im Spätfrühling und im Sommer auf ein Minimum absinkt. In unserem See jedoch nimmt die Bevölkerungsdichte vom März, wo das Minimum erreicht ist, bis zum September, wo das Maximum eintritt, allmählich zu, und weist kein Zurückgehen während des Sommers auf.

Um die Ursache dieser Erscheinung klar zu legen, haben wir zunächst der Produktionsperiode der *Corethra*-Larven eine kurze Besprechung zu widmen. Wir haben die aus jedem monatlichen Fange stammenden Exemplare nach ihrer Grösse geordnet, und sind dabei zu einem sehr interessanten Resultat gelangt.

Bei Betrachtung der Tabelle fällt es sofort auf, dass die Exemplare im März, im allgemeinen, sehr gross sind und kleine Individuen überhaupt nicht vorkommen. Das erste Auftretenn von kleinen Exemplaren fällt etwa in den Spätfrühling, während im Mai schon mässig entwickelte Individuen zum Vorschein kommen. In letzterem Monat ist ein wenn auch sehr geringer Prozentsatz von Puppen zu beobachten, doch scheinen solche Exemplare Spätlinge aus der vorigen Generation zu sein.

Die im Frühling ausgeschlüpften Larven erreichen im Sommer das Imago-Stadium und die Zahl der grossen Exemplaren geht stark zurück, wie dies auch MIYADI in gewissen Seen Japans (z. B. Sumiyoshi-Ike, See Yogo usw.) beobachtet hat.

In unserem See kommt es aber in dieser Periode wieder zu einem erneuten lebhaften Auftreten infolge der Entwickelung der folgenden Generation vor, und die Bevölkerungsdichte der *Corethra*-Larven im ganzen weist daher kein Zurückgehen während des Sommers auf.

Tabelle 10.

Prozentsatz der *Corethra*-Larven nach der Grösse im Laufe des Jahres (III, 1929—I, 1930).

Monat / Länge (mm)	III 1929	V	VIII	IX	XI	I 1930
1.5–1.9	0	0	35.3	15.4	0	0
2.0–2.9	0	49.1	35.3	46.1	36.3	0
3.0–3.9	0	38.6	0	30.7	27.3	43.7
4.0–4.9	25.0	7.0	0	7.7	36.3	37.5
5.0–	50.0	0	11.7	0	0	12.5
Puppen	25.0	5.2	17.6	0	0	6.3
Wassertemp. C°	20.6	26.6	24.5	28.7	21.8	19.7

Im Zusammenhang mit dem hohen Temperaturgang des Seewassers dauert die Fortpflanzung bis zum Beginn des Herbstes ununterbrochen fort. Larven der zweiten Generation überleben den Winter ohne starken Rückgang und einige von ihnen erreichen schon im Frühjahre das Imaginalstadium.

Die in unserem See vertretenen *Corethra* spp. erweisen sich demnach, in ihrer Gesamtheit und als einheitliches Ganzes betrachtet, als Dauerformen.

Obgleich die *Corethra*-Larven in ihrer Gesamtheit jährlich nur eine einmalige maximale Massenentfaltung aufweisen, scheint es doch, dass sie in unserem See wahrscheinlich zwei Generationen in einem Jahre besitzen. Die erste Generation beginnt etwa in der Mitte des Frühlings und erreicht schnell ihre Imago-Periode im Spätsommer; die zweite Generation beginnt, mit einer breiten Ausdehnung der Produktionsperiode (ungefähr zwei Monate) etwa im Spatsommer; ihre Imago-Periode wird erst nach der Überwinterung im Frühling erreicht und dauert bis zur Mitte desselben fort. Hieraus geht deutlich hervor, dass die beiden Generationen sich während der Monate vom Spatfrühling bis zum August teilweise überdecken, und weiter, dass die Imago-Periode der *Corethra* spp. vielleicht in die Zeit vom Frühjahre bis etwa Spatsommer fällt, da alle wahrend dieser Zeit entnommenen Proben, wie die Tabelle zeigt, die Puppenstadien enthalten.

Bei dieser Gelegenheit ist zu betonen, dass das vorstehend dargestellte Auftreten der *Corethra*-Larven, wegen der Schwierigkeit ihrer Identifizierung, ausschliesslich in ihrer Gesamtheit und als einheitliches Ganzes behandelt wurde.

Vertikalverteilung:

Wie allgemein bekannt, sind die *Corethra*-Larven als bathyphile Formen zu bezeichen. Sie beginnen ihr Auftreten im freien Wasser mit dem Sonnenuntergang und sinken mit dem Sonnenaufgang auf den Seeboden herab. Es ist uns aber unbekannt, ob die Larven die ganze Nacht hindurch ohne herabzusinken herumschwimmen oder nicht, in Ermangelung von Probeentnahmen während der tiefsten Nacht. Doch zeigt sich deutlich, dass die Bevölkerungsdichte in den frühesten Nachtstunden, bis etwa 21 h, allmählich zunimmt, und weiter dass dieselbe während des Frühmorgens, solange es noch dunkel ist, kein starkes Zurückgehen erkennen lässt.

Diese Verhältnisse gehen z. B. aus der Untersuchung im September in der Tabelle 11 mit genügender Klarheit hervor.

Es scheint aber, dass die *Corethra*-Larven während der Nacht keine bestimmte Vertikalverteilung aufweisen.

Was die Schnelligkeit der Aufwärts- und Abwärtsbewegung dieser

Tabelle 11.

Vertikalverteilung der *Corethra*-Larven. Die Ziffer in jeder Tiefe bezeichnet die Individuenzahl pro 1 L. des Seewassers.

	Uhr Tiefe(m)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
März 1929	0	0	0	0	0		0		0		0			0	0	0	0	0
	1.5	0	0	0	0		0		0		0			0	0	0	0	0.2
	2.5	0	0	0	0		0		0		0			0	0	0	0.2	0.4
	S.																0.2	0.6
	Sonnenaufgang: 5.55 h Sonnenuntergang: 18.10 h																	
Mai	0	0	0.2	0	0	0			0		0		0		0	0.4	0.4	0.2
	1.5	0.4	0	0		0			0		0		0		0	0.4	0.2	0.6
	2.5	0.2	0	0		0			0		0		0		0.2	0.8	0.6	0.6
	S.	0.6	0.2												0.2	1.6	1.2	1.4
	Sonnenaufgang: 5.11 h Sonnenuntergang: 18.38 h																	
August	0	0.2	0	0		0		0		0		0		0	0.2	0.6	0.8	0.6
	1.5	0.2	0.6	0		0		0		0		0		0	0.2	0.4	1.6	1.0
	2.5	0.8	0.2	0		0		0		0		0		0.2	0	0.8	0.4	1.6
	S.	1.2	0.8											0.2	0.4	1.8	2.8	3.2
	Sonnenaufgang: 5.35 h Sonnenuntergang: 18.25 h																	
September	0	0.6	0	0		0	0		0		0		0		0	0.4	1.2	1.0
	1.5	1.2	0	0		0	0		0		0		0		0.6	0.6	1.0	1.4
	2.5	1.4	0	0		0	0		0		0		0		1.4	1.2	0.6	3.0
	S.	3.2													2.0	2.2	2.8	5.4
	Sonnenaufgang: 5.45 h Sonnenuntergang: 17.55 h																	
November	0	0.2	0	0	0		0		0		0		0	0	0	0.6	0.6	0.4
	1.5	0.4	0	0	0		0		0		0		0	0	0.4	1.0	0.4	0.8
	2.5	0.6	0	0	0		0		0		0		0	0	0.4	1.4	0.2	0.4
	S.	1.2													0.8	3.0	1.2	1.6
	Sonnenaufgang: 6.16 h Sonnenuntergang: 17.10 h																	
Januar 1930	0	0	0	0		0			0		0		0		0	0.2	0.8	0.2
	1.5	0.2	0	0		0			0		0		0		0	0.2	0.2	0.8
	2.5	0	0.2	0		0			0		0		0		0	0.4	0.2	0.2
	S.	0.2	0.2													0.8	1.2	1.2
	Sonnenaufgang: 6.41 h Sonnenuntergang: 17.38 h																	

Arten anbelangt, so müssen wir zunächst die Ergebnisse für den September in Betracht ziehen. Zu dieser Zeit geht die Sonne um 17.55 h unter, also herrscht um 18 h schon Dämmerung; doch kommen die Larven zu diesem Zeitpunkt schon in der Wasserschichte von mehr als 1.5 m Tiefe vor.

Das Herabsinken beim Tagesanbruch scheint ebenfalls sehr plötzlich stattzufinden, weil hier die Sonne um 5.45 h aufgeht und schon um 6 h keine Individuen mehr zu finden sind, während sie um 5 h noch reichlich vorkommen.

Bei dieser Gelegenheit muss aber betont werden, dass die Schnelligkeit der Aufwärts- und Abwärtsbewegung der Larven beziehungsweise beim Sonnenuntergang und Tagesanbruch je nach den Entwickelungstadien etwas verschieden ist. Diese Verschiedenheit scheint wohl auf Unterschieden der Empfindlichkeit für die Lichtintensität, welche den Entwickelungsstadien der Larven gemäss wechseln mag, zu beruhen. Die allerkleinsten Individuen sind für die Lichtintensität verhältnismässig wenig empfindlich.

Betrachtet man die Tabelle, so fällt es auf den ersten Blick auf, dass, wie z. B. die Untersuchung im August zeigt, die Larven schon um 17 h und 18 h im Wasser auftreten, und weiter um 6 h noch im Wasser verharren, obgleich hier die Sonne um 5.35 h aufgeht und um 17.25 h untergeht. Hier ist der Umstand äusserst interessant, dass alle diese Larven zu den allerkleinsten Entwickelungsstadien gehören.

Die gleiche Erscheinung zeigt sich auch bei der Untersuchung im Mai. Im Gegensatz hierzu scheinen aber die voll entwickelten Individuen für die Lichtintensität viel empfindlicher zu sein, wie dies die Tabelle der Untersuchungen im November, Januar und März ständig ergibt.

Während dieser Monate treten nämlich keine Individuen am hellen Tage im freien Wasser auf und zwar wird das Einsetzen der Aufwärtsbewegung, von Sonnenuntergang an gerechnet, dem Alter der Larven gemäss allmählich verspätet.

Wie oben erwähnt, pflanzen sich die *Corethra* spp. während dieser Monate niemals fort, sondern es findet nur die Weiterentwickelung der Larven statt. Somit steht die schrittweise Verspätung der Periode der Aufwärtsbewegung vom November bis zum März mit dem Alter der Larven in völligem Einklang.

JUDAY (1921) macht in seinen eingehenden Untersuchungen über den See Mendota, Wisconsin, darauf aufmerksam, dass die sehr kleinen Larven in der Vertikalverteilung von den voll entwickelten abweichen, d. h. die letzteren während des hellen Tages sich in den Bodenschlamm eingraben, während erstere häufig in der Wasserschichte des tieferen Meso- oder des Hypolimnions auftreten.

Etwa die gleiche Tiefenverteilung der *Corethra*-Larven nach den Entwickelungsstadien gibt LUNDBECK (1926) für den Grebiner See an.

Diese Angaben über die Schichtungsverhältnisse der *Corethra*-Larven gemäss ihren Entwickelungsstadien mögen also als eine Bestätigung unserer Vermutung betrachtet werden.

Zusammenfassend dürfen wir sagen, dass die Empfindlichkeit der *Corethra*-Larven für die Lichtintensität ihrem Alter gemäss allmählich zunimmt.

Wir wollen jedoch nicht mit Sicherheit behaupten, dass die Schnelligkeit der Aufwärts- und Abwärtsbewegung der *Corethra*-Larven ausschliesslich in ihrer Empfindlickeit für die Lichtintensität ihren Grund hat. Immerhin glauben wir aber, dass bei diesen Arten die Empfindlichkeit für die Lichtintensität eine wichtige Rolle für die Schnelligkeit solcher Bewegungen spielt.

C. ANHANG.

Einfluss eines Sturmes auf die Biocoenose des Sees.

Wie schon oben wiederholt angegeben, wurde ich während der Beobachtung im August 1929 von einem Unwetter mit heftigem Wind und Regen überfallen.

Die Beobachtungen in diesem Monate begannen am 10ten, wo das Wetter noch heiter und windstill war, wie an den vorhergehenden Tagen. Am folgenden Tage aber erhob sich plötzlich ein heftiger Sturm, der bis zum Morgen des 13. August anhielt. Sofort nach dem Ende des Sturmes wurden am 13. und auch am 14. die Beobachtungen wieder aufgenommen.

Diese Serie der Untersuchungen ist insofern von grossem Interesse, als sie eine Antwort auf die Frage geben, in welchem Grade und in welcher Beziehung ein heftiger Sturm Einfluss auf die Biocoenose des Sees haben kann.

Zitugetutan ist, wie schon mehrmals erwähnt, ein verhältnismässig seichter, mässig grosser See mit einem engen Abfluss, und demgemäss verursacht heftiger anhaltender Regen eine auffällige Hebung des Wasserstandes und plötzliche Erniederung der Wassertemperatur sowohl an der Oberfläche, als auch in der Tiefe. Der Wasserstand am 13. war in der Abflussregion ungefähr 1 m höher als am 10. August. Die Temperatur des Seewassers zeigte am 13. einen Fall von 4°C gegenüber dem 10. (s. Tab. 12).

Auch trat eine schwache Braunfärbung des Seewassers ebenfalls ein und daher ist eine Veränderung des freilich nicht bestimmten Chemismus des Seewassers wohl denkbar.

Tabelle 12.

Bevölkerungsverhältnis einiger Planktonorganismen nach Temperaturerniederung infolge eines heftigen Sturmes (10.–14. August, 1929).

Arten / Datum	*D. stylata*	*P. mirum*	*R. cylind.*	*M. thermoc.* Nauplien	Wassertemp. °C	
					0 m	3 m
10. VIII	6.7	47.7	12.9	139.9	27.3	27.1
13. VIII	0.7	12.1	3.1	67.3	23.5	23.5
14. VIII	0.8	7.7	2.5	48.9	23.2	23.3

Solche plötzliche Veränderungen der Milieu-Bedingungen wirken auf die Planktonorganismen stets schädigend, indem wenigstens einige Arten so heftig beeinflusst werden, dass sich in der Periode nach dem Sturme ein beträchtliches Zurückgehen der Individuenzahl bemerkbar macht.

An eine Verdünnung der Bevölkerungsdichte durch die vermehrte Wassermasse mag ebenfalls gedacht werden, doch beruht ihr starkes Zurückgehen wohl hauptsächlich auf den Milieu-Veränderungen des Seewassers.

Extremes Zurückgehen wurde besonders bei den Rotatorien (*Diurella stylata*, *Pedalion mirum* und *Rattulus cylindricus*) und auch bei den Nauplien von *Mesocyclops thermocyclopoides* beobachtet (s. Tab. 12 und Fig. 26).

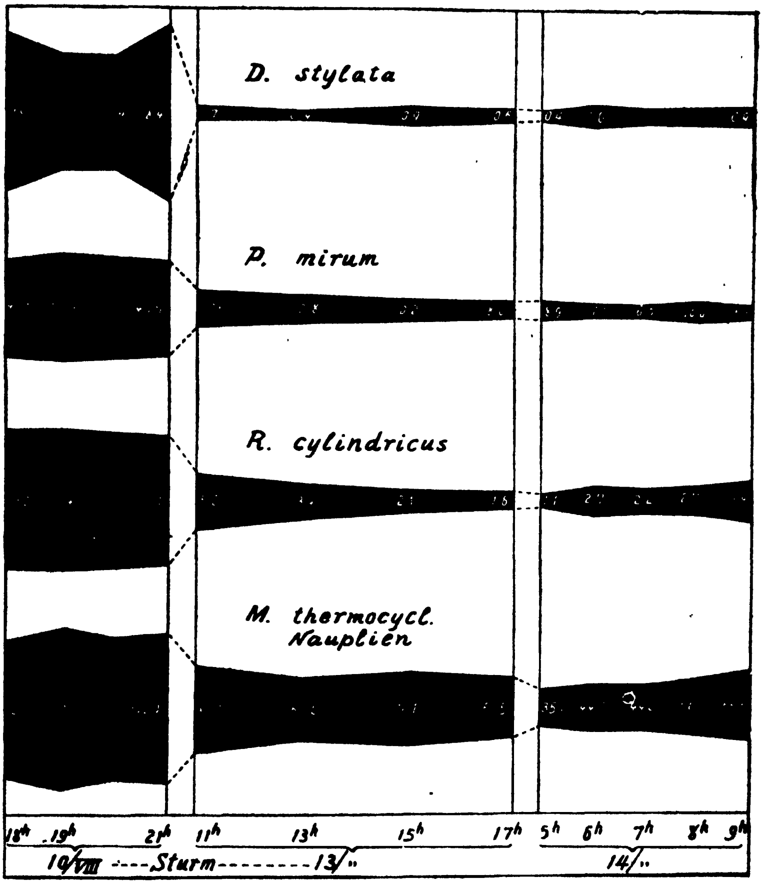


Fig. 26.
Schädigende Wirkung des Sturmes vom 10. bis 14. August, 1929 auf die Bevölkerungsverhältnisse einiger Planktonorganismen.

Betrachtet man die Tabelle, so ersieht man, dass das Zurückgehen der Individuenzahl durch die schädigende Wirkung des Sturmes 89.5% bei *D. stylata*, 75.9% bei *R. cylindricus*, 74.6% bei *P. mirum*, und 51.9% bei den Nauplien von *M. thermocyclopoides* betrug.

Die schädigende Wirkung durch die Veränderung der Milieu-Bedingungen des Seewassers scheint für diese Arten, mit Ausnahme von *D. stylata*, wenigstens während einiger Zeit anzuhalten.

LITERATURVERZEICHNIS

ALM, G. Monographie der Schwedischen Süsswasserostracoden usw. Zool. Bidr. f. Uppsala IV: 1- (1915).

APSTEIN, C. Das Plankton im Colombo-See auf Ceylon. Zool. Jahrb, Syst. XXV: 201- (1907).

BEAUCHAMP, P. Documents sur les Notomatidés à mastax forcipé, avec quelques remarques sur la nomenclature des Rotifères. Bull. Soc. Zool. France. 38: 288- u. 326- (1914).

BREHM, V. u. F. RUTTNER. Die Biocoenosen der Lunzer Gewässer. Int. Rev. 16: 281- u. 336- (1926).

——— Ueber Südasiatische Diaptomiden. Arch. f. Hydrobiol. XXII: 140- (1930).

BURCKHARDT, G. Hypothesen und Beobachtungen über die Bedeutung der vertikalen Planktonwanderung. Int. Rev. 3: 156- (1910).

COLDITZ, F. V. Beiträge zur Biologie des Mansfeldor Sees mit besonderen Studien über das Zentrifugenplankton und seine Beziehungen zum Netzplankton der pelagischen Zone. Zeits. f. wiss. Zool. 108: 520- (1914).

DEMOLL, R. Temperaturwellen und Planktonwellen. Arch f. Hydrobiol. 13: 313- (1922).

FADEEW, N. N. Das Rädertier Brachionus forficula Wierz. und seine Varietäten. Zool. Anz. 64: 285- (1925).

FELS, E. Vermessung und Morphologie des Walchenseebeckens. Arch. f. Hydrobiol., Suppl. VI: 7- (1928).

GAMS, H. Zur Schlammnomenklatur. Arch. f. Hydrobiol. XXI: 493- (1930).

HARADA, I. Studies on fresh-water fauna of Formosa I. A new Copepod species parasitic on Formosan fresh-water fishes. Journ. Soc Tropic. Agr., Taihoku Imp. Univ. 2; 71- (1930).

——— Studien über die Süsswasserfauna Formosas IV. Süsswasser-Copepoden aus Formosa. Ann. Zool. Japon. 13: 149- (1931).

HUDSON, C. T., and P. H. GOSSE. The Rotatoria; or Wheel-Animalcules both British and Foreign Vol. I, II u. Supp. (1889).

JENNINGS, H. S. Rotatoria of the United States II. A monograph of the Rattulidae. Bull. U. S. Fish Commission for 1902: 273- (1903).

JUDAY, CH. Observations on the larvae of Corethra punctipennis Say. Biol. Bull XL: 271- (1921).

KIKUCHI, K. Comparison of the diurnal migration of Plankton in eight Japanese lakes. Mem. Coll. Sci. Kyoto Imp. Univ., B. V: 27- (1930).

——— Diurnal migration of Plankton-Crustacea. Quart. Rev. Biol. V: 189- (1930).

KLIE, W. Die Ostracoden der Deutschen Limnologischen Sunda-Expedition. Arch. f. Hydrobiol., Suppl. XI: 447- (1932).

KRÄTZSCHMAR, H. Ueber den Polymorphismus von Anuraea aculeata Ehrbg. Int. Rev. 1: 623- (1908).

KROGH, A., und K. BERG. Ueber die chemische Zusammensetzung des Phytoplanktons aus dem Frederiksborg-Schlosssee und ihre Bedeutung für die Maxima der Cladoceren. Int. Rev. 25: 204- (1931).

LANGE, A. Unsere Kenntnisse von den Fortpflanzungsverhältnissen der Rädertiere. Int. Rev. 6: 257- u. 429- (1913).

LENZ, F. Zur Terminologie der limnologischen Zonation. Arch. f. Hydrobiol. XIX: 748- (1928).

LASTOCKIN, D. Beiträge zur Seetypenlehre. Arch. f. Hydrobiol. XXII: 546- (1930).

LINDEMANN, E. Die Peridineen der Deutschen limnologischen Sunda-Expedition nach Sumatra, Java, und Bali. Arch. f. Hydrobiol., Suppl. VIII: 691- (1931).

LÖNNERBLAD, G. Zur Kenntnis der Chemie einiger Humusseen. Arch. f. Hydrobiol. XXII: 355- (1931).

LOWNDES, A. G. Abyssinian Ostracoda. P. Z. S. London. III: 677- (1932).

MIYADI, D. Studies on the bottom fauna of Japanese lakes.

I. Lakes of Sinano Province. Jap. Journ. Zool. III: 217- (1931).

II. Mountain lakes of the tributaries of the River Tone with special reference to azoic zone. Dasselbe Journ. III: 259- (1931).

III. Lakes of the Kwanto Plain. Dasselbe Journ. IV: 1- (1932).

IV. Lakes of the Japanese sea coast of southern Honsyû. Dasselbe Journ. IV: 41- (1932).

V. Five lakes at the north foot of Mt. Fudi. Dasselbe Journ. IV: 81- (1932).

VI. Lakes of Southern Kyûsyû. Dasselbe Journ. IV: 127- (1932).

VII. Lakes of Hokkaido. Dasselbe Journ. IV: 223- (1932).

VIII. Lakes of north Japan. Dasselbe Journ. IV: 253- (1932).

IX. Lakes of Yodogawa-basin. Dasselbe Journ. IV: 289- (1932).

——— and. HAZAMA, N. Quantitative investigations of the bottom fauna of Lake Yogo. Dasselbe Journ. IV: 151- (1932).

MOLA, P. Fauna rotatoria italiana delle acque dolci, Int. Rev. 23: 428- (1930).

MÜLLER, G. W. Ostracoden aus Java. Mitt. Naturhist. Mus. Hamburg. 23. (1906).

MÜNSTER STROM, K. A physiographical and biological study of a mountain lake. Arch. f. Hydrobiol. XXII: 491- (1931).

NAUMANN, E. Die eulimnische Zonation. Einige terminologische Bemerkungen. Arch. f. Hydrobiol. XIX: 744- (1928).

——— Einige neue Gesichtspunkte zur Systematik der Gewässertypen. Mit besonderer Berücksichtigung der Seetypen. Arch. f. Hydrobiol. XX: 191- (1929).

——— Limnologische Terminologie Berlin. (1931).

REMANE, A. Gastrotricha. Kükenthal: Handbuch der Zoologie. II. (1929).

RUTTNER, F. Ueber tägliche Tiefenwanderung von Planktontieren unter dem Eise und ihre Abhängigkeit vom Lichte. Int. Rev. 2: 397- (1909).

——— Das Plankton des Lunzer Untersees, seine Verteilung in Raum und Zeit während der Jahre 1908-1913. Int. Rev. 23: 1- u. 161- (1929).

RYLOV, V. M. On the Eucopepodean fauna of Mantschuria. Ann. Mus. Zool. Acad. Sci. Russie XXIV: 52- (1923).

SHIBUYA. K. and K. HIGUCHI. Sapropel in Taiwan and its chemical properties. Journ. Soc. Trop. Agr., Taihoku Imp. Univ. 2: 272- (1930).

THIENEMANN, A. Tropische Seen und Seetypenlehre. Arch. f. Hydrobiol., Suppl. IX: 205- (1931).

UENO, M. The fresh-water Branchiopoda of Japan I. Mem. Coll. Sci. Kyoto Imp. Univ., B. II: 259- (1927).

——— Contribution to the knowledge of the Cladocera fauna of China. Int. Rev. 27: 234- (1932).

WESENBERG-LUND, C. Ueber pelagische Eier, Dauerzustände und Larvenstadien der pelagischen Region des Süsswassers. Int. Rev. 2: 424- (1909).

——— Rotatoria. Kükenthal, W.: Handbuch der Zoologie. II. (1929).

WOLTERECK, R. Zur Bildung und Entwickelung des Ostracodeneies. Zeits. f. wiss. Zool. 64: 596- (1898).

STUDIES ON THE DISINTEGRATION OF *BRANCHIURA SP.* BY METHYLENE BLUE

II. Respiratory Quotient and Respiration of Acidified Tissue

Siro KAWAGUTI

(Accepted for publication, April 24, 1934)

We have many papers on disintegration or cytolysis, but only a few of them are quantitative. Disintegration of *Branchiura sp.* in a solution of methylene blue was studied on a line of respiratory metabolism, especially of the respiratory quotient (1).

Barcroft-Warburg manometer method, which has been well fitted for the measurements of the repiratory quotient by DICKENS and SIMER(3) has been followed mainly. As to details, I modified some points regarding the technical side and also refered to the apparatus. The cup for the manometer has a central main chamber, and a surrounding annular space, for the barium hydroxide which is separated from the main chamber by a single wall. It has two appendices, one of which opens into the surrounding annular space and the other opening into the main chamber directly without connection with the annular space. The total capacity of the cup is about 20cc. In regard to CO_2, we cannot gain the same degree of exactness as in an O_2 consumption.

The specimen used was *Branchiura sowerbyi*, the same as that of my previous work. In each experiment five individuals were used together, which weighed usually wet from 90 mgm to 130 mgm. The volume of the test medium was 2 cc. Each 0.5 cc. barium hydroxide of saturated concentration and hydrochloric acid of 3 N were poured into definite places, under a continous flow of oxygen. The experiment was begun

---

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. VII, No. 8, August, 1934.]

after an immersion of the specimen in the test medium for twelve minutes. But in some cases the specimens were kept in distilled water and their respiration was measured. Then a certain volume of methylene blue solution, from a side chamber, was added to the test medium. In this case the carbon-dioxide out-put was calculated from the R. Q. in distilled water and the oxygen consumption at the time for the tip of methylene blue.

In distilled water the R.Q. was 0.82±0.02, at 30°C., and oxygen consumption was 0.416±0.0088 cc. per hour per gm. of wet weight.

The medium was carefully made of redistilled water containing phosphate buffers of M/1000, pH about 7.0.

From many determinations of $^{2}/_{1000}$% methylene blue, it resulted in the R. Q. being decreased in those of a longer period and increased in shorter ones. If there are any differences of R. Q. values in different parts of the body the phenomena may be explained. For example, if the tail portion has a large value of R. Q. and if at the time of disintegration, the intensity of respiration is predominating other parts, it may be possible that the R. Q. of the total body may be greatly affected by the R. Q. of the tail portion, and so on.

Then, I measured the respiratory metabolism of dismembered pieces, as the head, middle, and tail in distilled water. As shown in table 1,

Table 1.

Respiratory quotient and oxygen consumption of three cut pieces of body in distilled water at 30°C. Experiments were made after one hour of cutting. Each specimen was cut into almost equal weight of three pieces. Fifteen pieces of each portion were used in each experiment. Each datum is the mean of 4 experiments.

Portion	O_2 Consumption per hour per gm.	R. Q.
Head piece	0.400 cc.	0.94
Middle piece	0.388 „	0.78
Caudal piece	0.389 „	1.01

there is a significant axial gradient of values in R. Q. The table shows the decrease in the intensity of oxygen consumption in the middle piece, but not in the head and tail pieces. Such axial gradient of oxygen consumption and R. Q. was reported by OKADA.(3) We can easily calculate the R. Q. when such three pieces are put together in the same place, and this value is markedly larger than the value of intact animals. This decrease in oxygen consumption and increase in R. Q. may be the effect of the cutting. No objection, however, seems to be raised against number of cuts in each piece, as the results were the same for the specimen of which both tips of head and tail were cut off.

Table 2.

Respiratory quotient and oxygen consumption in $^{2}/_{1000}\%$ methylene blne solution. Each datum is the mean from 8 to 10 determinations, at 28°C.

Duration of experiment	O_2 consumption per hour per gm.	R. Q.	Stage of Disintegration
1 hour	0.376 cc.	0.95	3rd.
1.5	0.388 „	0.87	4th.
3.0	0.240 „	0.75	almost complete Disintegration

Such experimental facts seem to be very favorable for the explanation, but it is disproved. The conditions are the same even for the cut pieces, that is to say, when the duration of the experiment is long or the disintegration advances greatly, R. Q. is smaller and when the experiment is short R. Q. is larger than the normal value.

Table 2 and a part of table 3 show the effect of the duration of an experiment on oxygen consumption and the respiratory quotient in methylene blue. From these tables we can see that when the disintegration is gone further, the R. Q. decreases under normal value. The processes of change of R. Q. and of oxygen consumption will be discussed in future. The effect of illumination has also been taken into consideration. In the dark the oxygen consumption slightly decreases and the R. Q. becomes larger than in the normal. Both values are nearer to the values in distilled water than the normal. The specimen in darkness disintegrates slower than an illuminated one. Thence we may suppose that the change in darkness is due to the disintegration.

Whether the methylene blue actually may be activated by illumination and the methylene blue-lueco methylene blue system may be affected by light (Clark,(3) Harvey(4)) or not, it is not the main problem in this case.

Table 3 shows the effects of different concentration of methylene blue, on the R. Q. and the oxygen consumption. From this we can see that the disintegration occurs rapidly in concentrated solutions and R. Q. increases. In lower concentrations, where no or only slight disintegration takes place the R. Q. and the consumption of oxygen deviate a little or hold their normal values.

Table 3.

Effect of concentration of methylene blue on R. Q. at 30°C. Each datum is the mean from 4 to 6 determinations. Whole disintegration is divided into 6 stages. Details are given in (1).

Concentration of Methylene blue	Duration of Experiment	O_2 consumption per hour per gm.	R. Q.	Stage of Disintegration
$1\times10^{-2}\%$	40 min	0.539 cc.	0.93	5th
$5\times10^{-3}\%$	60 „	0.405 „	0.86	4th
„	170 „	0.251 „	0.76	Almost complete
„	600 „	0.092 „	0.62	Complete D. I. at 370 min.
$1\times10^{-4}\%$	55 „	0.453 „	0.82	1st

When the experiments are carried on until complete disintegration of the body or furthermore, the R. Q. decreases significantly. These facts led me to the next experiments that show how the R. Q. measures at instantaneous killing of the specimen, and how that of disintegrated fragments in methylene blue or in some other chemicals counts.

Table 4 shows the results of experiments, where the specimens are killed rapidly by HCl, at about 0.5 N in final concentration. R. Q. markedly increases. This fact may be explained partly by the rapid decomposition of living matter, in which certainly much CO_2 and also NH_3 may be produced. Probably, the process inhibits the respiration at first and not glycolysis, even if, it increases the glycolysis. The case

Table 4.

R. Q. and oxygen consumption during rapid killing by HCl. 30°C.

Exp. No.	O_2 Consumution	O_2 con. per gm. during whole course of killing	R. Q.
281	14.1 cub. mm.	56.6×10^{-3} cc.	1.57
282	11.4	53.2 „ „	1.23
283	12.6	51.2 „ „	1.55
287	11.3	49.7 „ „	1.76
288	12.8	61.2 „ „	0.89
289	12.9	58.4 „ „	1.32
	Mean.	55.0×10^{-3} cc.	1.40

seems to coincide with the results of RUNNSTRÖM(5) in cytolysis of sea urchin eggs. Although the chemical transformation in death of this animal is not yet clear, the disintegration may cause the oxidation of glycogen or such simple substances of theoretical high R. Q.

Production of carbon-dioxide more than in-take of oxygen by a system may induce the reduction of the theoretical R. Q. of the substance. This may suggest an interesting relation to the decrease of oxidation-reduction potential during cytolysis. (NEEDHAM,(6) CHAMBERS and others(7)).

The oxygen consumption for complete disintegration is remarkably larger than the value calculated from the living time in the corresponding concentration of HCl and the normal respiratory intensity. This may be caused by the convulsion at death. Furthermore some parts of oxygen, however, would be used for the liberation of excess energy which had been stored in the body structure of specimen. Such energy has been actually proved by LEPESCHKIN(9) in blood cells and fungi cells, and well discussed by NEEDHAM(7) and TAMIYA.(10)

The experiments on the later phase of disintegration were carried out with specimens which have been killed by methylene blue or by HCl. The experiments started when the specimens were disintegrated or killed completely.

Both acidified tissue and disintegrated fragments in methylene blue took up the oxygen in considerable quantities, without or with small production of carbon-dioxide. Such phenomena in acidified tissues have been reported by Amberson(11) and his school and by Needham.(12) Although the suggestions for the explanation of this phenomenon are given by the latter, I am not sure as to a discussion of it here.

We can summarize from above findings that the respiratory exchange during the disintegration phenomena by methylene blue or other substances may be divided into two processes, the first having high R. Q. value and strong intensity of respiration, and the second having low R. Q. and feeble intensity. The first is the rapid decomposition, and the second is the slow transformation of the disintegrated substances into the more stable states.

Bibliography

1. Kawaguti, S. This Memoires, 7, 57–69. (1932).
2. Dickens, F. and F. Simer. Biochem. Jour. 24. 905–13. (1930).
3. Okada, T. Dōbutsugaku Zassi 41, 410-7. (1929).
4. Clark, W. M., B. Cohen and H. D. Gibbs, Pub. Health Rep. U. S. A. 1017. (1925).
5. Harvey, N. E. Jour. Gen. Phy. 10, 103–110. (1926).
6. Runnstrom, J. Biochem. Z. 258. 257–79. (1933).
7. Needham, J. Chemical Embryology, Vol. 2. (1931).
8. Chambrs, R. L. V. Beck, and D. E. Gree, Jour. Exp. Biol. 10, 142–52. (1933).
9. Lepeschkin, W. W. Journ. Gen. Phy. 12, 345. (1932).
10. Tamiya, H. Acta Phytochimica, 6, 265–304. (1932).
11. Amberson, W. R, P. M. Armstrong, and W. S. Root. Proc. Ebp. Biol. and Med. 29, 31–3. (1931).
12. Needham, J. Proc. Exp. Biol. and Med. 30, 182–4. (1932).

EFFECT OF OXIDATION-REDUCTION POTENTIAL INDICATORS ON THE OXYGEN CONSUMPTION AND THE RESPIRATORY QUOTIENT OF *BRANCHIURA SOWERBYI*

Siro KAWAGUTI

(Accepted for publication, April 24, 1934)

The effect of a series of oxidation-reduction potential indicators upon the oxygen consumption of living cells was studied by GENEVOIS(1) in *Chlorella*, by BARRON and HOFFMAN(2) in sea-urchin eggs, by MICHAELIS and SALOMON(3) in red blood cells, and by CHAPHEAU(4) in oyster's tissues. The results of these authors did not coincide with each other in several points. The present writer, in connection with his previous work, is very interested in investigating the effect of these dyes on the respiratory quotient.

The method used for the determination of oxygen consumption and carbon-dioxide out-put was the manometric method of Warburg-Barcroft type. This was described in my previous work.(5)

The following medium was prepared just before the experiments and used as a control medium,

$NaCl$	$^{45}/_{1000}$ M
KCl	$^{3}/_{1000}$ M
$CaCl_2$	$^{5}/_{1000}$ M.

Phosphate buffer $^{1}/_{1000}$ M. pH of this solution was near 7.0. The test medium was made by adding 10^{-4}mol. of each dye to 100 cc. of this control medium.

Specimens used were *Branchiura sowerbyi*, as in my previous papers. After being collected from ditch mud they were kept in tap water for

---

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol VII, No. 3, August, 1934.]

one day. Then the specimens were transfered into the control medium for 30 minutes before each experiment. Five specimens, weighing 110 mgm to 150 mgm in total, were used together in each experiment. The condition of the specimens such as food, time of collection, weight of the body, were carefully regulated. The experiment started after a ten minutes immersien of the specimens in experimental medium, and was carried out for one hour, excepting in the cases when dyes are very toxic. Temperature of experiments was 25.0° ± 0.02°C.

Table 1, figures 1 and 2 show the results of experiments. Each datum for individual dye is the mean value from 9 to 15, most frequently 12 experiments

If those data with dyes of high toxicity, as cresyl blue, Bindschedler's green, and dimethyl-p-phenylene diamine are set aside, we can find in figure 1 the increased oxygen consumption in the range of phenol-indophenol and methylene blue, and also in lower E'_0. In potassium-ferricyanide, quinone and indigo-tetra, tri, and disulfonate, the oxygen consumption remains at the control value.

Methylene blue does not show a maximum oxygen consumption. Gallocyanine effects almost similarlly with methylene blue as stated by MICHAELIS and SALOMON.

The mechanism of increased oxygen consumption by these high E'_0 dyes was treated by FISHBERG and DOLIN.⁽⁷⁾ The respiratory pigment of *Branchiura sowerbyi* seems to differ from haemoglobine, but similar mechanism, not so much alike, would be expected.

Regarding the speed of process it is worth mentioning here that BARRON⁽⁸⁾ found the linear relation between logarithms of time for auto-oxidation of dyes and their E'_0 values, with a few exceptions.

Table 1.

Experimental results. Each dye in 10^{-3}M. Temperature 25°C±0.02°C.

Dyes	E'_0 at pH 7	O_2 Consumption per hour per gm.	R. Q.	Stage of disintegration
Potassium-ferricyanide	0.43	0.308±0.0048	0.87±0.025	1st.
Dimethyle-p-phenylen diamine	0.38	0.657±0.0032	0.87±0.014	3rd. killed
Quinone (10^{-4}M)	0.278	0.315	0.90	
Phenolindophenol (i)	0.229	0.465±0.0066	0.89±0,011	no or 1st.
Phenol blue (i)	0.227	0.379	0.94	
Bindschedler's green (i)	0.224	0.365±0.0052	1.06±0.026	4th
Toluylene blue (i)	0.115	0.511±0.0090	0.88±0.007	4th
m-toluylendiamine-indophenol (i)	0.115	0.450±0.0067	0.84±0.013	2nd.
Lauth's violet	0.065	0.572±0.0073	0.80±0.011	1st. or 2nd.
Cresyl blue	0.032	0.632±0.0012	0.98±0.014	4th or 5th
Methylene blue	0.011	0.409±0.0070	0.78±0.013	2nd or 3rd.
Gallocyanine	0.013	0.429±0.0065	0.83±0.010	1st.
Indigotetra-sulfonate (Na)	−0.046	0.300±0.0060	0.79±0.007	no
Indigotri-sulfonate	−0.081	0.295±0.0076	0.84±0.015	no or 1st.
Indigodi-sulfonate	−0.125	0.299±0 0037	0.79±0.015	no
Cresyl violet	−0.167	0.380±0.0066	0.85±0.020	no
Phenosafranine	−0.242	0.425±0.0039	0.87±0.016	1st.
Janus green	−0.258	0.367±0.0058	0.83±0.020	1st or 2nd.
Neutral red	−0.340	0.512±0.0056	0.94±0.012	1st or 2nd.
Control medium		0.310±0.006	0.76±0.008	no.

(i) These dyes were synthesized by myself according to CLARK and others. (12).

Gallocyanine was synthesized according to Schultz's Farbstoff-Tabellen.

Methylene blue was Merck's Zn-free sample.

Neutral red was Kahlbaum's pH-indicator. Same results were obtained by using Merck's histological stainings.

Ferricyanide and quinone were Schering-Kahlbaum's.

Other dyes without mention are Grübler's histological stainings.

E'_0-values are taken from WURMSER (13), and not direct measurement of my samples.

At the 5th column the state of the specimens at the end of each experiment were indicated by the same denotation, according to my previous paper. Total process of disintegration was divided into six stages.

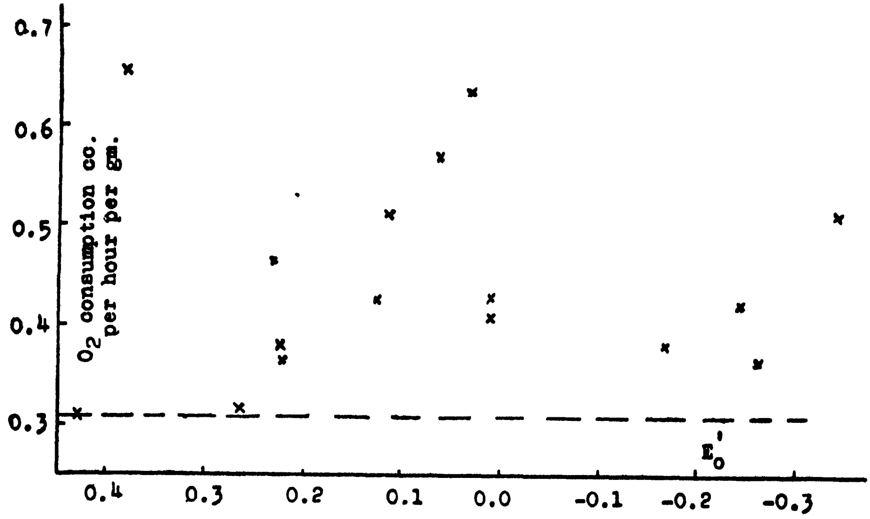


Fig. 1.

Oxygen consumption with several dyes in concentration of 10^{-3} M. Ordinate shows oxygen consumption per hour per gm of wet weight Abscissa shows the E'_0 value of each indicator dye at pH 7.0 A broken line shows the value in the control medium.

Phenosafranine, Janus green and neutral red, especially in the last case, increase the oxygen consumption. These results contradict against the results from majourity of authors, but agree with that of GENEVOIS in *Chlorella*. These discrepancies may be caused by the differences of materials, concentration of dyes, and permeability of contact surface.

As the effect of concentration several determinations were carried out in several dyes at 30°C. The results were summarized in table 2. In lower concentrations no or slight decrease of the oxygen consumption is observed in Janus green and phenosafranine, but not in neutral red. There were no significant changes of the oxygen consumption and of the R. Q. for about 3 hours immersion in diluted dye solutions.

Fig. 2 shows the R. Q. of each dye refering to E'_0 of dye. Excepting the cases with high toxic dyes, we have increased R. Q. at higher E'_0 ranges. Slight or no effect can be seen in the range of Lauth's violet and indigo-disulfonate. At the lower E'_0 range there occurs again a significant increase of R. Q.

Di-, tri-, and tetra-sulfonate of indigo give no effect, probably owing to their non permeable nature. The effect of the high toxic dye can be explained similarly with the case of methylene blue in higher concentration. That is to say, either disintegration or rapid killing results in the increase of the oxygen consumption and in the R. Q.

Table 2.

Effect of concentration of dyes on oxygen consumption and respiratory quotient of *Branchiura sowerbyi*, at 30.0°C.

Medium	Concentration	O_2 consumption cc. per hour per gm.	percentage of control	R. Q.	Stage of disintegration
Control medium		0.515 cc.	108 %	0.79	no.
Thionine	3.8×10^{-4}M	0.598	116	0.86	3rd.
Cresyle blue	5×10^{-4}M	0.730	142	0.90	4th. killed
"	1×10^{-4}M	0.899	173	0.91	3rd.
"	1×10^{-5}M	0.613	119	0.88	1st.
Nile blue	2.3×10^{-5}M	0.614	119	0.87	5th.
"	5.6×10^{-6}M	0.620	120	0.83	5th.
"	2.3×10^{-6}M	0.534	104	0.86	3rd.
Methylene blue	5.4×10^{-5}M	0.558	103	0.79	
Toluidin blue	3.3×10^{-4}M	0.604	117	0.80	3rd.
"	3.3×10^{-5}M	0.517	100	0.84	3rd.
Indigodisulfonate	1×10^{-3}M	0.508	99	0.73	no.
(3 hours immersion)	"	0.475	92	0.71	no.
Cresyle violet	3.4×10^{-4}M	0.504	98	0.76	no.
Phenosafranine	3.1×10^{-4}M	0.582	113	0.85	1st.
"	3.1×10^{-5}M	0.433	84	0.66	no.
(8 hours immersion)	"	0.520	101	0.73	no.
Janus green	2.1×10^{-4}M	0.453	88	0.88	2nd.
"	2.1×10^{-5}M	0.423	82	0.79	1st.
Neutral red	3.5×10^{-4}M	0.681	132	0.91	3rd.
"	7.0×10^{-5}M	0.546	106	0.84	2nd.
(8 hours immersion)	"	0.586	114	0.80	1st.

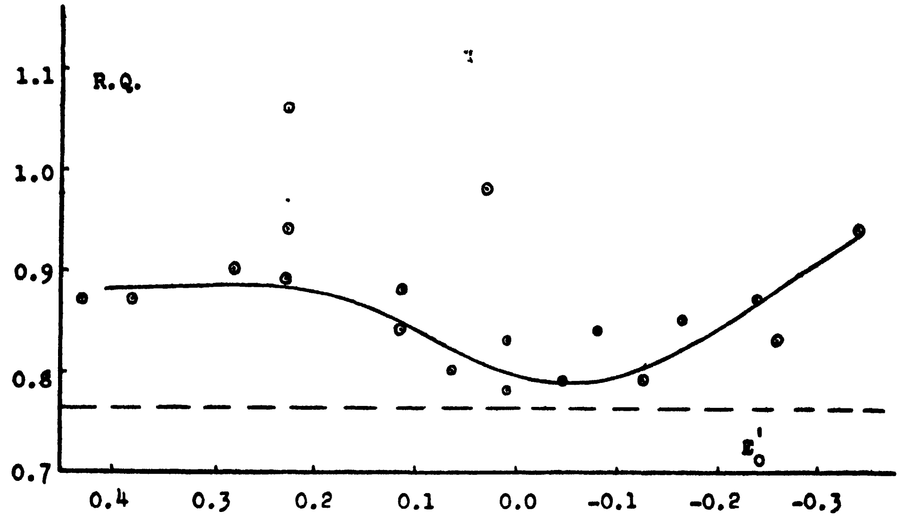


Fig. 2.

Respiratory quotient of *Branchiura sowerbyi* in 10^{-3}M dyes. Ordinate shows the R Q Abscissa shows the E'_0 of indicators used. The broken line shows the value in control medium. A line drawn freely to show a general tendency of the change of R. Q. for non or less toxic dyes

Some examples of intermediate effect by some diluted solutions can be seen in table 2. Strictly speaking, the data of table 1, with that of table 2 should not be compared directly, as the temperatures were changed. We can see, however, what the general tendency is. (The rise of temperature slightly increases the R. Q.)

On the R. Q. under the effect of oxidation-reduction potenetial indicator dyes little has been published, but Barron and Hoffman(8) obtained 0.75 for the R. Q. of red blood cells in methylene blue solution, notwithstanding the fact that they had some evidence of increased carbo-hydrate oxidation. Decreases of R. Q. values by methylene blue were reported by Himwich *et al*(8) in cerebral cortex, testicle, kidney, and liver tissues. Runnsrom(9) studied finely the effect of dimethyl-p-phenylene-diamine and hydroquinone on the R. Q. of sea urchin eggs. These two reagents increased the R. Q. to unity from normal value 0.9. Recently, Dodds and Greville(10) communicated the effect of dinitro-cresol on kidney tissue. The R. Q. of the tissue increased to 0.87 from the control value 0.78. They calculated the R. Q. of increased respiration and found it as unity. Thus, the increased respiration was considered as the results of carbohydrate oxidation.

There would be many possibilities of the processes of these mechanisms in affecting the R. Q. As already has been discussed in other place,(11) concerning only the oxidizing substances, there are two possibilities of changing the R. Q., qualitative and quantitative. Primarily the case when total oxidizing substances are changed can be seen in Fig. 2. Secondly, the R. Q. for increased respiration was calculated in each case of table 1. And it turned out, as might be predicted from the figures 1 and 2, that (a) the R. Q. was higher than unity at the ranges of higher E'_0 (b) the R. Q. was less than unity at the middle E_0, and (c) the R. Q. increased to the unity or more at the lower E'_0.

From these results we can say, as the general conceptions, that in the increased respiration, carbohydrate is mainly used for the combustion, especially in the cases (a) and (c).

What is the mechanism of oxidizing mainly carbohydrate in these cases?

The condition in the case (b) seems to be different from that of (a) and (c). That is to say, these dyes having a little higher E'_0 than the potential of tissues, do not affect the respiratory mechanism, but increase the velocity of reaction.

To explain these effects of dyes on the respiratory quotient more clearly, further experiments are very desirable on several different materials with several series of indicators.

Bibliography

1. Genevois, L. Protoplasma, 4, 67–87. (1928).
2. Barron, E. S. G., and L. A. Hoffman. Jour. Gen. Phy. 13, 483–94. (1930).
3. Michaelis, L. and K. Salomon. Biochem. Z. 234, 107–115. (1931).
4. Chapheau, M. Theses Fac. Science Bordeanx.
5. Kawaguti, S. This Memoires. 7, 141–146. (1934).
6. Fishberg, W. H. and B. T. Dolin. Jour. Biol. Chem. 101, 159–71. (1933).
7. Barron, E. S. G. Jour. Biol. Chem. 97, 287–302. (1932).
8. Himwich, H. E. and M. H. Hurlburt. Proc. Exp. Biol. Med. 30, 904–6. (1933).
9. Runnström, J. Protoplasma 15. 532–65. (1932).
10. Dodds, E. C. and G. D. Greville, Nature 132. 966–7. (1933).
11. Kawaguti, S. Jour. Fac Science, Tokyo Imp. Uni. Sec. IV, 3, 189–204. (1933).
12. Clark, W. M., B. Cohen, H. D. Gibbs and M. Phillips. U. S. Public Health Reports. Studies on Oxidation-Reduction. V, VI, XI, XV. (1924–28).
13. Wurmser, R. Oxidation et Reduction. (1930).

昭和九年八月二十八日印刷
昭和九年八月三十日發行

編纂兼發行者	臺北帝國大學理農學部
印刷者	頴川首 臺北市大正町二ノ三七
印刷所	株式會社臺灣日日新報社 臺北市榮町四ノ三二

購買申込所	株式會社臺灣日日新報社 臺北市榮町四ノ三二
同	丸善株式會社 東京市日本橋區通二丁目

I.A.R.I. 75

INDIAN AGRICULTURAL RESEARCH INSTITUTE LIBRARY, NEW DELHI.

Date of Issue	Date of Issue	Date of Issue

GIPNLK—H-40 I.A.R.I.—29-4-5—15,000